

# **Subsurface Investigation Work Plan Mayflower Mill and Tailings Impoundments Area**

**July 2015**

Prepared for:

Sunnyside Gold Corporation  
5075 South Syracuse Street  
Suite 800  
Denver, CO 80237

Prepared by:



2500 55th Street, Suite 200  
Boulder, Colorado 80301

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B	Standard Operating Procedures (SOP)
C	Health and Safety Plan (HASP)
D	Geophysical Investigation Work Plan

## LIST OF ACRONYMS

ABA	Acid Base Accounting
DQO	Data Quality Objective
EPA	United States Environmental Protection Agency
HASP	Health and Safety Plan
NAG	Net Acid Generating
QAPP	Quality Assurance Project Plan
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
SPLP	Synthetic Precipitation Leaching Procedure
TA	Target Analyte
TP	Tailing Impoundment
USGS	U.S. Geological Survey

## 1.0 INTRODUCTION

This Subsurface Investigation Work Plan (Work Plan) was prepared on behalf of Sunnyside Gold Corporation (Sunnyside) to investigate the characteristics of the tailings and native materials underlying the tailings in the Mayflower Mill and Tailings Impoundments Area near Silverton, Colorado (Figure 1-1). The Work Plan describes the sampling and analysis plan (SAP) for the drilling, core sampling, and monitoring well installation program planned for the summer of 2015. A geophysical investigation is also described in this Work Plan. A multi-media work plan has been prepared as a separate document that describes the additional surface water sampling (i.e., low-flow sampling), groundwater sampling, pore water sampling, sediment sampling, and solid phase media sampling activities planned for the summer and fall of 2015 (Formation Environmental 2015a).

There are four Mayflower tailings impoundments located approximately one mile to the northeast and upstream of Silverton on the right bank of the Animas River, as shown on Figure 1-2. These tailing impoundments are further described in Section 2.0 of this Work Plan. As shown on Figure 1-2, the study area in the upper Animas River Valley extends along the river and the floodplain from just upstream of the confluence of the upper Animas River and Arrastra Creek downstream to the 14<sup>th</sup> Street bridge crossing in Silverton. The focus of this subsurface investigation is the Mayflower Mill and Tailings Impoundment Area. Additional locations outside of this study area may also be investigated, as directed by Sunnyside. Investigations in these areas would be conducted in accordance with this Work Plan.

The upper Animas River basin and its tributaries are intensely mineralized, and natural weathering of mineralized rock degrades the basin's surface water quality. Streams within the basin that are considered representative of natural-background conditions (i.e., unaffected or minimally affected by mining activity) can be acidic ( $\text{pH} < 3.0$ ) with trace metals concentrations, including zinc, copper, and manganese, above aquatic life standards (USGS, 2007). Environmental conditions in the upper Animas River basin also reflect influences from the extensive historic mining and milling activities that occurred over the past 150 years, including mining in areas upstream of the Mayflower Mill and Tailings Impoundments Area and on the left bank of the Animas River (the opposite bank from the Mayflower Mill and Tailings Impoundments Area). Mine adits and historic mine waste rock piles are present at numerous locations, and historic mills typically discharged tailings to the Animas and its tributaries.

Aside from this introductory section, the structure of this Work Plan is as follows. A discussion of the background information is presented in Section 2.0. Section 3.0 identifies the data needs, intended data uses, and data quality objectives (DQOs) for the subsurface investigation. The SAP for the drilling, core sampling, and monitoring well installation effort is presented in Section 4.0 along with a list of target analytes (TAs). Reporting of the results for the subsurface

investigation is described in Section 5.0. References cited in this Work Plan are listed in Section 6.0. Appendices to this Work Plan are listed below:

- Appendix A: Quality Assurance Project Plan (QAPP)
- Appendix B: Standard Operating Procedures (SOP)
- Appendix C: Health and Safety Plan (HASP)
- Appendix D: Geophysical Investigation Work Plan

## 2.0 BACKGROUND

The Mayflower tailings impoundments are located approximately one mile to the northeast and upstream of Silverton on the right bank of the Animas River (Figure 1-2). Tailings Impoundment No. 1 is the most upstream, and subsequent impoundments are numbered in the downstream direction.

Tailings stored in Tailings Impoundment Nos. 1 through 4 were produced by flotation milling at the Mayflower Mill.<sup>1</sup> As such, the impoundments are expected to consist of relatively fine grained material, with sand-sized particles predominating near the impoundment embankments and silts and clays predominating nearer the native hillsides where ponds were maintained during operation and clarified water was decanted.

Tailings Impoundment Nos. 1 and 2 were reclaimed between 1991 and 1992. Tailings Impoundment No. 3 was reclaimed in 1992 and Tailings Impoundment No. 4 was reclaimed between 2004 and 2006, although the majority of the top cover was completed in 2004. In general, reclamation was accomplished by re-grading the side slopes to achieve a stable configuration and by covering the slopes and top surfaces with locally derived growth medium.

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<sup>1</sup> Minor exceptions include materials from other areas deposited in the Mayflower tailings impoundments.

### 3.0 DATA QUALITY OBJECTIVES AND DATA NEEDS

This section identifies the study questions, data needs, and intended data uses for the subsurface investigation of the Mayflower Mill and Tailings Impoundments Area (Figure 1-2). The chemicals of interest for the subsurface investigation are identified as the TAs in Section 4.0 and are consistent with the chemicals of concern for soil/sediment identified by the Environmental Protection Agency (EPA) in its SAP/QAPP (EPA, 2015).

This section is organized to be consistent with EPA's guidance for application of its DQO process (EPA, 2006), which includes the seven steps listed below.

1. State the Problem
2. Identify the Goals of the Study
3. Identify Information Inputs
4. Define the Boundaries of the Study
5. Develop the Analytic Approach
6. Specify Performance and Acceptance Criteria
7. Develop the Plan for Collecting Data

Application of the DQO process results in identification of the specific types and quality of data needed to support the goals of the subsurface investigation.

#### 3.1 DQO Step 1 - State the Problem

Previous investigations in the study area have identified elevated levels of metals in the waters of the upper Animas River where it passes by the Mayflower Mill and Tailings Impoundments Area. The materials present in the tailings impoundments may or may not be sources of metals to the river via leaching and subsurface transport by groundwater. However, the current sources of metals and their effects on river water quality remain uncertain. Therefore, additional data are needed to better understand the relationship, if any, between the Mayflower Mill and Tailings Impoundments Area and metals concentrations in surface water of the upper Animas River adjacent to and downstream from this area as well as left bank sources. More specifically, additional physical and chemical data are needed to evaluate the various materials present in the Mayflower Mill and Tailings Impoundments Area, including the total metals concentrations and leaching potential, as well as the hydrostratigraphy.

#### 3.2 DQO Step 2 - Identify the Goals of the Study

The key study questions to be answered by the subsurface investigation are as follows:

- What are the physical characteristics (e.g., thickness, texture, and moisture conditions) of the tailings impoundment materials?
- What is the composition and extent of native alluvial materials underlying the Mayflower Mill and Tailings Impoundments Area, if present?
- What are the concentrations of the TAs in the Mayflower Mill and Tailings Impoundments Area and how do those concentrations change with location and depth?
- How does the metals leaching potential vary among the tailings and the materials underlying the Mayflower Mill?
- What are the chemical conditions within tailings impoundment materials, and what types of bacterial organisms are currently present?
- Are conditions in the impoundments suitable to support bacterial populations that may limit metals migration to groundwater?

### 3.3 DQO Step 3 - Identify Information Inputs

Previous investigations provided preliminary characterization of the surface water flow conditions and surface water quality in the study area in 2002 and 2003 (Kimball, et al., 2010). However; there are significant data gaps in the characterization of the materials disposed in the four tailings impoundments, and the hydrostratigraphy and groundwater conditions within the impoundments have not been evaluated.

The following types of information are needed to address the study goals listed in DQO Step 2.

- Concentrations of the TAs in the subsurface core samples collected from the Mayflower Mill and Tailings Impoundments Area.
- Acid generation potential and metals leachability in the subsurface core samples collected from the Mayflower Mill and Tailings Impoundments Area.
- Physical characteristics (e.g., thickness, texture, and moisture conditions) and vertical extent of the impoundment and native materials underlying the impoundments.
- Identification of water-bearing zones (i.e., aquifers)
- Characterization of bacterial organisms present in the retrieved core samples.

### **3.4 DQO Step 4 – Define the Boundaries of the Study**

The purpose of the study is to characterize current conditions within and beneath the Mayflower Mill and Tailings Impoundments Area. The spatial boundaries for the study area are shown on Figure 1-2. Additional areas outside of the study area may be investigated, as directed by Sunnyside. Any subsurface investigations implemented outside of the current study area would be conducted in accordance with this Work Plan.

The temporal boundary of the study is the 2015 field season. The study will be conducted during one field season to obtain characterization data collected during a relatively constant set of field conditions.

### **3.5 DQO Step 5 – Develop the Analytic Approach**

In accordance with the data needs described above in DQO Step 3, representative samples of solid materials will be collected from the Study Area for characterization of the physical and chemical properties of interest, including concentrations of the TAs. These samples will be collected from subsurface borings that penetrate the materials underlying the Mayflower Mill and the impoundments, as described in Section 4.1.2 of this Work Plan. Additional field data will also be collected during borehole drilling to address the need for information on the moisture content and groundwater elevations in the impoundments. The general sampling and analysis approach developed to address these data needs is summarized in the QAPP (Appendix A).

### **3.6 DQO Step 6 – Specify Performance or Acceptance Criteria**

Performance and acceptance criteria are defined and controlled through implementation of sampling and analytical methodologies designed to ensure that the data generated are of adequate quality for project decision-making purposes. If the quality assurance activities for sample collection and analysis specified in project documents are met, and the analytical precision and accuracy requirements specified in the QAPP (Appendix A) are met, the resulting data will be usable for characterizing the conditions in the study area and addressing the study goals stated herein.

The laboratory analysis methods need to provide quantitative data at concentrations low enough for meaningful comparison to applicable standards, as needed. The proposed analytical methods and the target method detection limits and reporting limits typically achieved using the analysis method are specified in the QAPP (Appendix A).

### **3.7 DQO Step 7 – Develop the Plan for Obtaining Data**

The basic sampling and analysis approach described in DQO Step 5 will be implemented in accordance with the more detailed plans presented in Section 4.0. The plans developed for data

collection are considered resource effective approaches that provide the quantities and quality of data needed to answer the subsurface investigation questions consistent with the analytical approach (Step 5) and performance criteria (Step 6) described above.

## **4.0 SAMPLING AND ANALYSIS PLAN**

This section presents the SAP for the proposed subsurface investigation that has been developed to characterize the Mayflower Mill and Tailings Impoundments Area. An adaptive management approach will be employed for this study and for future studies. As such, the investigation will have an iterative methodology that allows for modification to the SAP as warranted by site conditions as they become better understood.

The QAPP is provided in Appendix A. Standard operating procedures (SOPs) that describe the various procedures and methodologies for the subsurface investigation are provided in Appendix B.

### **4.1 Target Analytes**

The solid phase media TAs for this investigation are summarized in Table 4-1. These TAs are inclusive of the solid phase media TAs developed by the EPA for its SAP/QAPP for the 2015 sampling events planned in the Upper Animas mining district (EPA, 2015). Additional TAs have also been selected to achieve the DQOs.

TAs for groundwater are discussed in a separate multi-phase SAP/QAPP that includes surface water, groundwater, and solid phase media (soil and sediment) (Formation Environmental, 2015a).

### **4.2 Drilling and Monitor Well Installation**

A total of seventeen (17) boreholes will be completed to characterize Mayflower Mill and Tailings Impoundments Area. Table 4-2 and Figure 4-1 summarize and illustrate, respectively, the borehole locations. Two boreholes will be completed at the Mayflower Mill (DH-16 and DH-17), four boreholes will be completed at TP-1 (DH-12 through DH-15), two boreholes will be completed at TP-2 (DH-10 and DH-11), one borehole will be completed at TP-3 (DH-9), and eight boreholes will be completed at TP-4 (DH-1 through DH-8). The following describes the drilling and well installation program.

#### **4.2.1 General Drilling Procedures**

Cascade Drilling of Aurora, Colorado, a licensed driller in the State of Colorado, will use a rotasonic drill rig to complete the boreholes. All boreholes will be advanced through the tailings and into the underlying native materials, which are expected to be comprised of alluvium and/or bedrock. Where alluvium is encountered, the borehole will be advanced through the alluvial

materials to bedrock (if possible). Eight-inch diameter boreholes will be advanced using a double-cased system with an inner core barrel and larger override casing. Using this method, the borehole will be continuously cased to the total depth and unconsolidated materials will be continuously cored to the total depth. Sections of core will be extruded from the core barrel into a plastic sleeve and subsamples of these cores will be collected for textural/lithological and laboratory analysis, as described below. Drilling waste including all cuttings and fluids will be disposed of on-Site near each borehole location, as deemed appropriate by the field staff. At selected borehole locations drilling waste may be temporarily containerized, as needed, based on site conditions.

#### 4.2.2 Core Sampling

The core sampling plan is described below and the sample collection methods are described in the QAPP (Appendix A). The textural and lithological characteristics of the core will be described in accordance with the visual and manual methods described in the QAPP.

Although tailings are generally relatively homogeneous due to the milling process prior to deposition, Sunnyside recognizes multiple periods of tailing deposition and anticipates that there may be multiple sub-populations of tailings from a geochemical standpoint. As such, a sufficient number of samples will be collected to support the risk management strategy at a 95% confidence interval, to be consistent with CERCLA guidance. This approach is based on the *Methodology for Adequacy of Sampling of Mill Tailings and Mine Waste Rock*, described by Runnells and others (1997).

The following sampling approach will be used to provide a sufficient number of samples for characterization of materials present in the impoundments at the desired confidence level. In the absence of changes in color, texture or lithology, an approximate one-kilo sample will be collected from the upper portion of each five foot interval collected from the core barrel at each drilling location. The samples collected every five feet will be submitted to the laboratory for an aqua regia analysis of their total metals content (refer to the QAPP in Appendix A for a description of laboratory methods associated with these preliminary analyses). The results of these analyses will be used as a geochemical baseline to screen for chemically distinct materials, if any, present in the tailings impoundments, determine the population profile(s), and select the number of samples to adequately represent each population for additional analyses following the method identified by Runnells and others (1997) as described below.

Following completion of the total metals analyses, concentration histograms will be constructed for key elements that are relevant to achieve the DQOs (e.g., cadmium, lead, zinc, etc.). Review of the histograms will identify distinctive subpopulations for further characterization. Using the total metals data available for each of the subpopulations identified from these histograms, a sub-set of samples will be selected to represent the observed distribution within major sub-populations, to include no fewer than 10 samples. The number of samples ultimately selected

from each subpopulation for ABA, NAG method, and SPLP tests (Table 4-1) will depend on the variability of the material characteristics.

#### **4.2.3 Abandonment of Borings**

Abandonment of boreholes that are not selected for completion as monitoring wells will be conducted by filling the boreholes with bentonite chips or pellets and then introducing water to hydrate the chips or pellets. This abandonment method meets or exceeds the abandonment requirements of Rule 16 (Standards for Plugging, Sealing, and Abandoning Wells and Boreholes) of the Colorado "Water Well Construction Rules."

#### **4.2.4 Monitoring Well Construction**

Boreholes to be completed as monitoring wells will be selected in the field. The target zone for well completion is the native materials underlying each tailings impoundment. 4-inch diameter schedule-40 polyvinyl chloride (PVC) wells will be completed with 10-foot screened intervals. Water bearing zones will be identified during drilling and logging. Final well construction details will be determined in the field. The wells will be completed with a sand filter pack extending above and below the well screen followed by a transition seal and an annular seal to the surface in conformance with Colorado "Water Well Construction Rules," effective date January 1, 2005. All wells will be completed at the surface with a locking steel casing monument and concrete pad to direct runoff away from the borehole annulus.

Monitoring wells installed under this Work Plan will be developed and sampled after a minimum of 24 hours have elapsed following well construction to allow grout to set and bentonite to fully hydrate. Well development will be conducted in accordance with SOP No. 8, *Monitoring Well Development* (Appendix B).

#### **4.3 Groundwater Sampling and Water Level Measurement**

Groundwater sampling and water level measurements will be conducted in accordance with the methods and procedures described in a separate multi-media SAP/QAPP that includes surface water, groundwater, and solid phase media (soil and sediment).

#### **4.4 Geophysical Investigation Work Plan**

A geophysical investigation will be conducted in the Study Area as described in the work plan included in Appendix D.

## 4.5 Sample Labeling

Each sample that is collected in the field will be labeled for future identification. Sample labels may be filled out as completely as possible by a member of the sampling team prior to the start of the day's field sampling activities. Samples will be labeled with all necessary information on pre-printed waterproof labels using waterproof ink. At a minimum, each sample label shall contain the following information:

- location identification;
- sample identification number (including codes for site location, sample matrix, and sample type, described in further detail below);
- date and time of sample collection;
- analyses required;
- method of preservation, if used;
- sample matrix;
- sample depth, if applicable.

Each sample shall be assigned a unique sample identification number. These numbers are required for tracking the handling, analysis, and verification or validation status of all samples collected during monitoring. Each sample identification number will identify the sampling location and type of sample. Samples to be collected will include planned soil phase media samples and QC samples.

For planned solid samples, sample identification numbers will be assigned using several codes as follows:

Sampling Event – Location - Depth – Matrix Type

SS0815-DH1-05-SO

The first field in the identification number identifies the project location and event month and year. This example includes the project location, "SS" (Sunnyside) and an event month and year of "0815" (August 2015).

The second field in the identification number identifies the location of the sample. In this example, "DH1" indicates borehole sample location as the sampling location. Location identifiers have already been established and are included on Table 4-2.

The third field identifies the sample depth. The depth is indicated in feet below ground surface (bgs) and in this example "05" indicated 5 feet bgs.

The fourth field identifies the sample matrix type. The matrix type is defined as "SO" to designate the matrix is solid.

Note that additional codes may be added as the project proceeds. The additions will be communicated immediately to the field staff and data management team.

The required QC samples are described in the QAPP (Appendix A). For QC samples, sample identification numbers will be assigned using the same coding described above, but also including information needed by the Formation project team to recognize the field QC samples, for example:

Sampling Event – Location - Depth - Matrix

SS0815-DH100-01-SO

[where DH100 and the Depth are for a non-existent sample location]

For multiple QC samples, the depth field will be numbered sequentially for each sample (e.g., rinsate blank = 01, duplicate = 02, etc.)

Field personnel will record the sample identification code with the type of QC sample (e.g., rinsate blank) and the time of sample collection in field log books.

Samples will be immediately labeled in the field and sample numbers shall be recorded at the time of sampling in field notes and on field data collection forms.

## 5.0 REPORTING

Upon the completion of the subsurface investigation, a field summary report will be prepared to briefly describe the findings of the investigation. These results will be incorporated into an annual report, which will summarize the findings from all phases of investigation conducted during 2015. This report may also include recommendations for additional investigative work.

## 6.0 REFERENCES

EPA, 2002. Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan, EPA QA-5S, 2002

EPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4. February

EPA, 2015. Sampling and Analysis Plan/Quality Assurance Project Plan, 2015 Sampling Events, Upper Animas Mining District, San Juan County, Colorado. Final Revision 0, June.

Formation Environmental, 2015a. Surface Water, Groundwater, and Solid Phase Media Investigation Work Plan, Mayflower Mill and Tailings Impoundments Area. July.

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Kimball, B.A., Runkel, R.L., and Walton-Day, K., 2010. An Approach to Quantifying Sources, Seasonal Change, and Biogeochemical Processes Affecting Metal Loading in Streams: Facilitating Decisions for Remediation of Mine Drainage. Applied Geochemistry 25 (2010) 728-740.

Runnells, D.D.; Shields, M.J.; and Jones, R.L.. 1997. Methodology for Adequacy of Sampling of Mill Tailings and Mine Waste Rock.

USGS, 2007. Integrated Investigations of Environmental Effects of Historical Mining in the Animas River Watershed, San Juan County, Colorado. Professional Paper 1651 Chapter E7, Characterization of Background Water Quality. Prepared by M.A. Mast, P.L. Verplanck, W.G. Wright, and D.J. Bove.

## Tables

**Table 4-1**  
**Target Analytes for Solid-Phase Media (Borehole Core Samples)**

Target Analyte	EPA Method Number	MDL <sup>8</sup> (mg/kg)	PQL <sup>8</sup> (mg/kg)	Maximum Hold Time (days)	Sample Volume	Preservative
Aluminum	6010	3	15	180	10 grams	None
Antimony	6020	0.2	1			
Arsenic	6020	0.1	0.5			
Barium	6010	0.3	1.5			
Beryllium	6010	1	5			
Cadmium	6010	0.5	2.5			
Calcium	6010	10	50			
Chromium	6020	0.25	1.25			
Cobalt	6010	1	5			
Copper	6010	1	5			
Fluoride (Soluble)	D3761	0.1	0.5	--	25 grams	
Iron	6010	2	10	180	10 grams	
Lead	6010	3	15			
Lithium	6010	0.8	4			
Magnesium	6010	20	100			
Manganese	6010	0.5	2.5			
Mercury	7471	0.0002	0.001	28		
Molybdenum	6010	2	10	180		
Nickel	6010	0.8	4			
Selenium	6020	0.05	0.25			
Silica	6010	42.8	214			
Silver	6010	1	5			
Strontium	6010	0.5	2.5			
Thallium	6020	0.05	0.25			
Vanadium	6020	0.1	0.5			
Zinc	6010	1	5			
Other						
SPLP extraction and analysis for metals listed above	1312/6020 <sup>3</sup>	--	--	180	100 grams	None
Acid-Base Accounting (ABA)	600/2-78-054	--	--	--	10 grams	None
Total Element Analysis (above metals)	IMS 12B	--	--	--	10 grams	None
Net Acid Generation (NAG)	VOL <sup>4</sup>	--	--	--	--	--
DNA Extraction for Molecular Biology	See Note 5	--	--	--	1500 grams	None

Notes:

- = not applicable
- SPLP = Synthetic Precipitation Leaching Procedure
- Multi-element analysis by ICP-MS following aqua regia digestion
- pH 4.5 to 7 end points
- DNA extraction followed by illumina sequencing and data reduction
- MDL = Method detection limit
- PQL = Practical quantitation limit
- Targeted MDLs and PQLs are listed. Laboratories routinely adjust these values, and therefore, reported MDLs and PQLs may differ slightly from those listed here

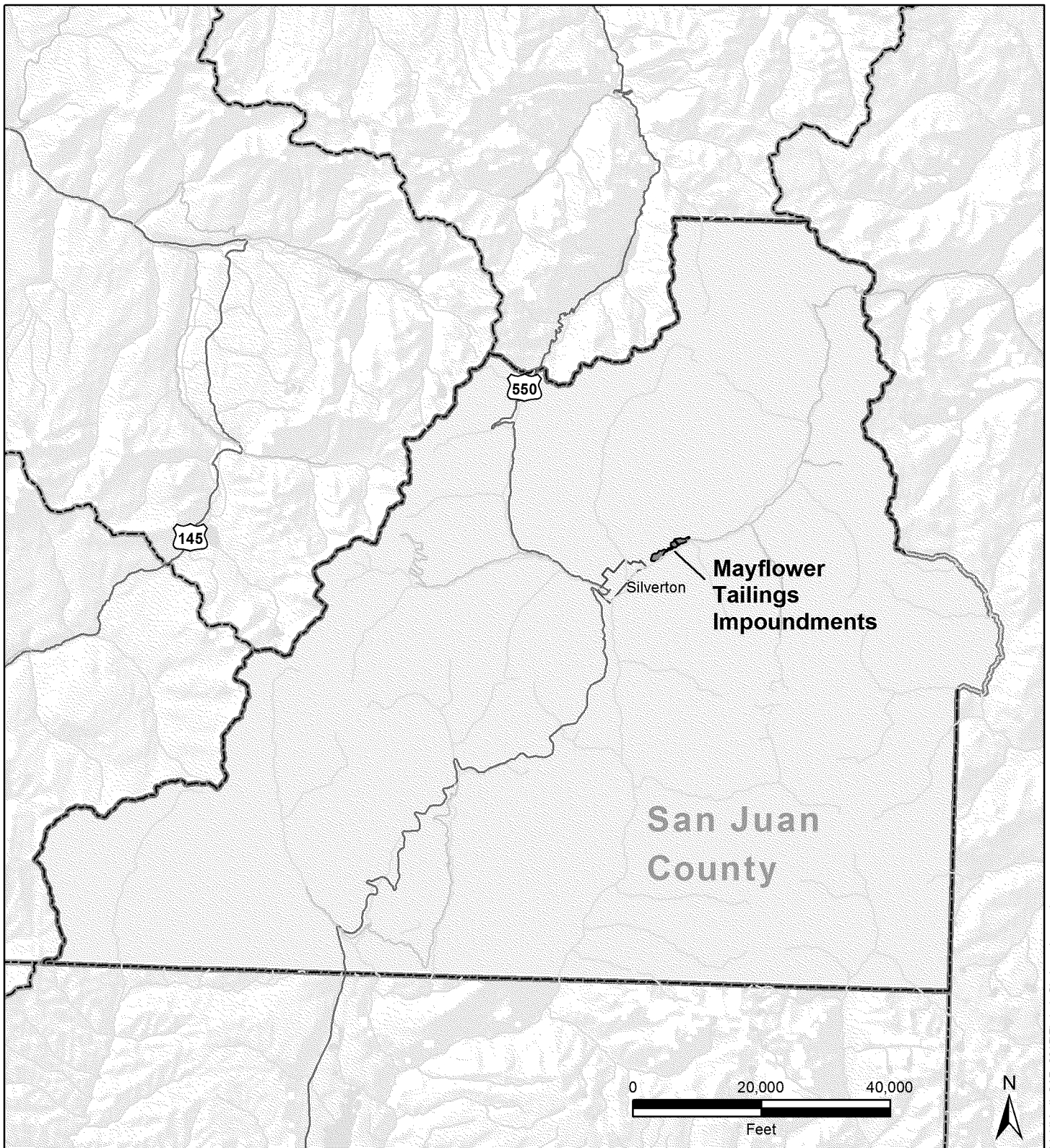
**Table 4-2**  
**Borehole Locations**

Borehole ID	Tailings Impoundment
DH-12	TP-1
DH-13	TP-1
DH-14	TP-1
DH-15	TP-1
DH-16	TP-1
DH-17	TP-1
DH-10	TP-2
DH-11	TP-2
DH-9	TP-3
DH-1	TP-4
DH-2	TP-4
DH-3	TP-4
DH-4	TP-4
DH-5	TP-4
DH-6	TP-4
DH-7	TP-4
DH-8	TP-4

Notes:

1. TP-1 = Tailings Impoundment No. 1; TP-2 = Tailings Impoundment No. 2;  
TP-3 = Tailings Impoundment No. 3; TP-4 = Tailings Impoundment No. 4

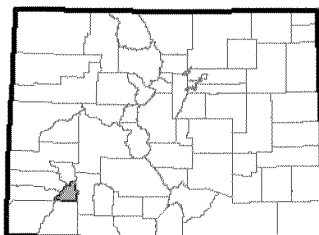
## Figures



## Legend

-  Roads
-  Highways
-  Silverton, CO
-  Mayflower Tailings Impoundments
-  Counties

### Location of The Sunnyside Mine in San Juan County, Colorado



## SUNNYSIDE GOLD

SILVERTON, CO

FIGURE 1-1

## SITE LOCATION MAP

DATE: JUL 01, 2015

BY: DKG

FOR: BGH

**FORMATION**  
ENVIRONMENTAL

S:\GIS\5065-001-Sunnyside-UpperAnimas\p1\MultiMedia\SAP\_2015\Fig1\_1\_SiteLocation.mxd



### Legend

- Perennial River or Stream
- Study Area (Approximate Boundary)

Base data sources: 2013 NAIP (National Agriculture Imagery Program) Aerial Photo Rivers and Streams from USGS NHD (National Hydrography Dataset) modified locally using aerial photo

010002000

Feet

N

SUNNYSIDE GOLD

SILVERTON, CO

FIGURE 1-2

SITE PLAN AND STUDY AREA

DATE: JUL 08, 2015

BY: AJ, DKG

FOR: BGH

FORMATION ENVIRONMENTAL

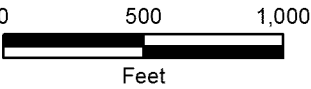
S:\GIS\5005-001-Sunnyside-UpperAnimas\p1\Sonis\SAP\_2015\Fig1-2\_SitePlanStudyArea.mxd



**Legend**

- Borehole Locations
- Buried Channel
- Stream/River: Perennial
- Study Area (Approximate Boundary)

Base data sources: 2013 NAIP (National Agriculture Imagery Program) Aerial Photo  
Rivers and Streams from USGS NHD (National Hydrography Dataset)  
modified locally using aerial photo



<b>SUNNYSIDE GOLD</b>	
SILVERTON, CO	
FIGURE 4-1	
<b>BOREHOLE LOCATIONS</b>	
DATE: JUL 08, 2015	<b>FORMATION</b> ENVIRONMENTAL
BY: DKG FOR: NBB	

S:\GIS\5005-001-Sunnyside-UpperAnimas\p1\SonicSAP\_2015\Fig5-1\_PropBoreAndWellLocs.mxd

## **Appendix A – QAPP**

**Subsurface Investigation Work Plan  
Mayflower Mill and Tailings Impoundments  
Area**

**APPENDIX A - Quality Assurance Project Plan  
(QAPP)**

**July 2015**

Prepared for:

Sunnyside Gold Corporation  
5075 South Syracuse Street  
Suite 800  
Denver, CO 80237

Prepared by:



2500 55th Street, Suite 200  
Boulder, Colorado 80301

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## LIST OF ACRONYMS

ABA	Acid Base Accounting
bgs	below ground surface
CCB	Continuing Calibration Blank
CCV	Continuing Calibration Verification
CLP	EPA Contract Laboratory Program
COC	Chain of Custody
DO	Dissolved Oxygen
DQOs	Data Quality Objectives
EDD	Electronic Data Deliverable
EPA	United States Environmental Protection Agency
HASP	Health and Safety Plan
ICB	Initial Calibration Blank
ICP	Inductively Coupled Plasma
ICPMS	Inductively Coupled Plasma-Mass Spectrometer
ICV	Initial Calibration Verification
LCS	Laboratory Control Sample
LFB	Laboratory Fortified Blank
MDL	Method Detection Limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NAG	Net Acid Generating
ND	Not Detected
NFG	National Functional Guidelines
ORP	Oxidation-Reduction Potential
PARCC	precision, accuracy, representativeness, comparability, and completeness
PQV	Practical Quantitation Verification
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
QL	Quantitation Limit
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure

SPLP        Synthetic Precipitation Leaching Procedure  
USCS       Unified Soils Classification System

## 1.0 INTRODUCTION

This Quality Assurance Project Plan (QAPP) comprises Appendix A of the Subsurface Investigation Work Plan for the Mayflower Mill and Tailings Impoundments Area (Work Plan). The purpose of this QAPP is to describe the quality assurance and quality control (QA/QC) policies and procedures that will be used during data collection and evaluation conducted in support of the subsurface investigation proposed to characterize the tailings impoundment materials and associated groundwater conditions in the study area. There are four tailings impoundments which are associated with the Mayflower milling operation. The tailings impoundments are located approximately one mile to the northeast and upstream of Silverton, Colorado on the right bank of the Animas River.

The QAPP describes the measures that shall be employed during the subsurface investigation to assure that data generated are of a known and defensible quality in relation to the overall objectives of the investigation. These measures will assure that the precision and accuracy of program data are known and documented; sample collection, analysis, and reporting are complete; and samples are representative of tested environmental media. This plan also provides guidance for documentation of information collected in the field, including field quality control data; maintenance of documented sample custody and laboratory analytical procedures; and quality control data for data verification and validation.

The QAPP was prepared in accordance with Environmental Protection Agency (EPA) guidance on Quality Assurance Project Plans (EPA, 2002; EPA QA/G-5) and EPA Requirements for Quality Assurance Project Plans (EPA, 2001; EPA QA/R-5). It is comprised of the following four basic project plan elements:

- project management;
- data generation and acquisition;
- data review, validation, and usability; and
- data assessment and oversight.

The subsections that follow provide the four EPA project plan elements (EPA, 2002), and each presents the topics applicable to that element with appropriate site-specific content, as needed for planning the subsurface investigation.

## **2.0 PROJECT MANAGEMENT**

This section addresses project administrative functions and project concerns, goals, and approaches to be followed during implementation of the subsurface investigation.

### **2.1 Problem Definition and Background**

The upper Animas River basin and its tributaries are intensely mineralized, and natural weathering of mineralized rock degrades the basin's surface water quality. Streams within the basin that are considered representative of natural-background conditions (i.e., unaffected or minimally affected by mining activity) can be acidic ( $\text{pH} < 3.0$ ) with trace metals concentrations, including zinc, copper, and manganese, above aquatic life standards (USGS, 2007). Environmental conditions in the upper Animas River basin also reflect influences from the extensive historic mining and milling activities that occurred over the past 150 years, including mining in areas upstream of the Mayflower Mill and Tailings Impoundments Area and on the left bank of the Animas River (the opposite bank from the Mayflower Mill and Tailings Impoundments Area). Mine adits and historic mine waste rock piles are present at numerous locations, and historic mills typically discharged tailings to the Animas and its tributaries.

Previous investigations in the study area have identified elevated levels of metals in the waters of the upper Animas River where it passes by the Mayflower Mill and Tailings Impoundments Area. The materials present in the tailings impoundments may be sources of metals to the river, via leaching and subsurface transport by groundwater. The current sources of metal loads and their effects on river water quality remain uncertain, and the metals loading associated with release and transport from the tailings impoundments has not been well characterized. Additional data are needed to better understand the relationship, if any, between the Mayflower Mill and Tailings Impoundments Area and metals concentrations in the surface water of the upper Animas River adjacent to and downstream from this area as well as left bank sources. More specifically, additional physical and chemical data are needed to evaluate the various materials present in the tailings impoundments, including their total metals concentrations and leaching potential, as well as the hydrostratigraphy and groundwater conditions within and beneath the impoundments.

### **2.2 Project Description**

The Work Plan presents the rationale and scope of data collection and monitoring activities planned to achieve the investigation objectives described above. The data collection activities associated with the subsurface investigation are described in detail in Section 4.0 of the Work Plan.

## 2.3 Project Organization

The subsurface investigation is being conducted by Sunnyside Gold Corporation (Sunnyside).

Sunnyside's responsibilities include preparation of project planning documents, collection of data needed to complete the subsurface investigation and data analysis and interpretation as needed to complete the investigation.

Sunnyside's project team for the subsurface investigation includes:

- Formation Environmental LLC (Formation), Boulder, CO (environmental services contractor); and
- ACZ Laboratories (ACZ), Steamboat Springs, CO (analytical laboratory contractor).
- SGS Canada Inc., Burnaby, BC (analysis and testing laboratory contractor)

**Sunnyside Program Manager** (Pat Maley, Sunnyside).

Oversees scheduling and management of all technical and non-technical aspects of the project (e.g., field activities, data collection, data analysis, report preparation, scheduling, costing) and serves as primary point of contact with agency representatives.

**Sunnyside Technical Lead** (Linda Schmoll, Ph.D., Sunnyside).

Reports to Sunnyside's Program Manager and reviews all technical aspects of the project, including work plans, QAPPs, data analyses, data reports, etc.

**Sunnyside Field Representative** (Terry Turner, Sunnyside).

Reports to Sunnyside's Program Manager and oversees all field aspects of the project, including sample collection, measurements, and data collection.

**Sunnyside Site Manager** (Larry Perino, Sunnyside).

Reports to Sunnyside's Program Manager and serves as the local liaison and provides access and historical knowledge for the mine site.

**Formation Project Manager** (Brian Hansen, P.E., Formation)

Oversees scheduling and management of all technical and non-technical aspects of the project (e.g., field activities, data collection, data analysis, report preparation, scheduling, costing) and reports to the Sunnyside Program Manager. Directs the Field Investigations Manager and Project QA Manager. Ensures that all field personnel understand the scope of work including QA/QC requirements. Responsible for ensuring that the sampling methods and data analyses

reflected in the Sampling and Analysis Plan (SAP) meet the objectives of the Work Plan. Reviews and approves project plans and all project deliverables.

**Field Investigations Manager** (Nat Beal, P.G., Formation)

Plans and supervises sampling and other field activities and coordinates acquisition of any necessary permits. Schedules and manages various field tasks (e.g., sample collection, measurements, data collection) and is responsible for sample transport to the laboratory. Responsible to the Sunnyside and Formation Project Managers for implementation of field sampling activities, QA/QC measures, and health and safety program requirements defined in the Appendix C of the Work Plan. The Field Investigations Manager is also responsible for ensuring that field staff have appropriate, hands-on training, properly utilize the project Standard Operating Procedures (SOPs; Appendix B of the Work Plan), and have reviewed the project Health and Safety Plan (HASP; Appendix C of the Work Plan) and are conducting field work in a safe manner at all times.

**Project QA Manager** (Kathy Tegtmeyer, Ph.D., Formation)

Responsible for coordinating the development and approval of the QAPP and its supporting procedures and for maintaining the current, approved version of the QAPP for use on the project. The QA Manager participates in the review and approval of all project deliverables, assists with establishing laboratory contracts, acts as a day-to-day liaison with the laboratories, directs field and laboratory audit activities, coordinates any subsequent corrective and preventive actions, if needed, and communicates regularly with the Formation Project Manager and Field Investigations Manager regarding any laboratory or data validation concerns. The QA Manager will also oversee data validation efforts and coordinate the resolution of any necessary corrective actions resulting from data validation activities, including any quality issues that may be resolved during field activities (i.e., resampling to replace unusable samples).

**Contracted-Laboratories** - ACZ Laboratories Project Manager (Max Janicek, ACZ), SGS Canada Project Manager (To Be Determined)

Reviews the project QAPP and ensures laboratory resources are available, reviews final analytical reports produced by the laboratory, coordinates scheduling of laboratory analyses, and supervises in-house chain-of-custody procedures.

## **2.4 Quality Objectives and Criteria for Measurement Data**

This section describes the quality of the data needed to address the study objectives as well as the measurement performance criteria established to assess the field and laboratory data quality. Measurement performance criteria are established by defining acceptance criteria and quantitative or qualitative goals (e.g., control limits) for precision, accuracy, representativeness,

comparability, and completeness (PARCC). The definitions of PARCC are provided below along with the acceptance criteria for data collected in support of this investigation.

This section is specific to the solid phase media samples described in the Work Plan. The data quality objectives and criteria for groundwater sampling are described separately in the *Surface Water, Groundwater, and Solid Phase Media Investigation Work Plan* (Formation 2015).

#### **2.4.1 Data Quality Objectives**

The data quality objectives (DQOs) for this program are presented in Section 3.0 of the Work Plan. Consistent with EPA guidelines (EPA, 2006), the DQOs describe the systematic planning of data collection activities to assure that the proper type, quality, and quantity of data are collected. The DQOs will be fulfilled by implementation of these QA and QC activities during data collection in support of the investigation:

- Following specific sampling designs (refer to the Work Plan);
- Adherence to standardized procedures for field measurements, sampling, sample handling, and sample chain of custody (COC) procedures;
- Collection and analyses of field and laboratory QC samples, as discussed in Section 3.4.1 and in Section 3.4.2, respectively;
- Analyses of samples in accordance with standard method protocols selected to meet the project's measurement performance goals (Section 2.4.3) and detectability requirements (Section 3.4.2);
- Adherence to the laboratory analysis methods, and their associated quality control steps, specified for analyses of environmental samples (Section 3.4.2);
- Implementation of laboratory-specific preventative maintenance measures;
- Data review and reduction by the laboratories;
- Data validation; and
- Quality auditing and corrective/preventative action processes, as described in this QAPP.

#### **2.4.2 Measurement Performance Criteria - Definitions**

The definitions of PARCC are provided below along with the acceptance criteria for data collected in support of the investigation. Equations for calculation of precision, accuracy, and completeness are also provided in Table A2-1.

##### Precision

Precision is the level of agreement among repeated measurements of the same characteristic. There are two general forms of uncertainty. The first is the random error component of the data

collection process. The second is inherent stochastic variability, which cannot be eliminated but can be described.

Data precision is assessed by determining the agreement between replicate measurements of the same sample and/or measurements of duplicate samples. The overall random error component of precision is a function of the sampling and analytical precision and is assessed by the analysis of field duplicates. The analytical precision is determined by the analysis of field duplicates by laboratories and by replicate analyses of the same sample. An analytical duplicate is the preferred measure of analytical method precision. When analytes are present in samples at concentrations below or near the quantitation limit (QL), precision may be evaluated using duplicate analyses of laboratory prepared samples such as duplicate laboratory control samples (LCS/LSCD) and duplicate laboratory matrix spike samples (MS/MSD).

Precision can be measured as relative percent difference (RPD) or as relative standard deviation (RSD; also known as a coefficient of variation). Formulae for both are presented in Table A2-1.

### Accuracy

Accuracy is the degree of difference between the measured or calculated value and the true value. It is a measure of the bias or systematic error of the entire data collection process. Potential sources of systematic errors include:

- sample collection methods;
- physical or chemical instability of the samples;
- interference effects during sample analysis;
- calibration of the measurement system; and
- contamination.

Data accuracy or analytical bias may be evaluated by the analysis of laboratory control samples (LCS) and/or matrix spike (MS) samples, with results expressed as a percentage recovery measured relative to the true (known) concentration (refer to Table A2-1 for percent recovery calculations).

Field equipment and laboratory blanks may be analyzed to assess artifacts introduced during sampling, transport, and/or analysis that may affect the accuracy of the data. In addition, initial and continuing calibration verification samples (ICV and CCV) and initial and continuing calibration blanks (ICB and CCB) may be used to verify that the sample concentrations are accurately measured by the analytical instrument throughout the analytical run.

### Representativeness

Data representativeness is defined as the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or environmental conditions. Representativeness is a qualitative parameter that is most concerned with the proper design of the sampling program. Representativeness of samples shall be achieved through the careful selection of sampling locations and methods. The sampling program described in Section 4.0 of the Work Plan has been designed to provide samples that are representative of the medium being sampled as well as a sufficient number of samples to meet the project DQOs.

### Comparability

Data comparability is defined as the measure of the confidence with which one data set can be compared to another. Comparability is a qualitative parameter but must be considered in the design of the sampling plan and selection of analytical methods, quality control protocols, and data reporting requirements.

### Completeness

Completeness refers to the amount of useable data produced during a sampling and analysis program. The procedures established in this QAPP are designed to ensure, to the extent possible, that data shall be valid and usable. To achieve this objective, every effort shall be made to collect each required sample and to avoid sample loss.

## **2.4.3 Measurement Performance Goals**

This section identifies numerical goals for precision, accuracy, and completeness for the various environmental media. Failure to meet these goals shall be considered in the data validation process described in Section 4.0.

### Precision

Precision shall be determined on field data and laboratory analysis data by the analysis of field duplicates, laboratory replicates, matrix spike, and matrix spike duplicate results and evaluation of the RPD for these various paired measurements. The RPD goals for measures of precision associated with the analytical methods are presented in Tables A2-2 through A2-4.

### Accuracy

Sampling accuracy shall be determined by the collection and analysis of equipment blanks, at the frequencies described in Section 3.4.

Laboratory accuracy is determined by the analysis of calibration and method blanks, calibration verification samples, laboratory control samples or standard reference materials, and matrix spike samples. Method blank goals shall be that blanks contain less than the laboratory's QL for each target parameter. Accuracy goals for the specific laboratory analysis methods that will be relied on to generate the metals data for the investigation are summarized in Tables A2-2 through A2-4.

### Representativeness

Representativeness is addressed by the description of the sampling techniques and the rationale used to select the sampling locations. Sampling methods are established by the SOPs provided in Appendix B of the Work Plan. Sample representativeness is also evaluated using the RPDs for field duplicate results and by a review of the results of field blanks (i.e., equipment blanks as appropriate to sampling methods).

Representativeness of individual sample analyses will be described on the basis of results obtained from associated laboratory quality control samples. The representativeness of sample analyses will be considered acceptable as long as any detectable concentrations of analytes in associated field and method blanks are less than the QL.

### Comparability

Comparability shall be ensured by analyzing samples obtained in accordance with appropriate SOPs and the referenced standard laboratory analysis methods. All data should be calculated and reported in units consistent with standard reporting procedures so that the results of the analyses can be compared with those of other laboratories, if necessary. In general, data shall be reported in µg/L for water matrices.

### Completeness

The project's completeness goals are 95 percent for analyses of solid-media samples.

## **2.5 Training Requirements**

Field personnel shall be trained in the requirements of the Work Plan and this QAPP at a project meeting prior to the initiation of field activity. All personnel shall read the Work Plan documents, including this QAPP, prior to the start of field work and shall acknowledge that they have read the documents at the time of the project meeting. In addition, prior to conducting sampling activities, the Field Investigations Manager, or designee, shall review field procedures and sampling requirements in order to better ensure that samples are collected and handled according to Work Plan and QAPP requirements. Field personnel will also be trained in the use of field equipment, decontamination procedures, and COC procedures in accordance with SOPs used for this project (refer to Appendix B of the Work Plan). One hard copy of the current

approved version of the Work Plan shall be maintained for ready-reference purposes in the field vehicle or field office. All field team members shall have access to \*.pdf format files of the complete Work Plan through their personal laptop computers.

## **2.6 Documentation and Records**

This section describes the management of project documents and records, including this QAPP. All field documentation will be conducted in accordance with the procedures described in SOP No. 1, *Field Documentation* (Appendix B of the Work Plan).

### **2.6.1 Field Logbooks**

Documentation of observations in the field provides information on conditions at the time of sampling and a permanent record of field activities. Field observations and data collected during sampling activities will be recorded with waterproof ink in a permanently bound weatherproof field log book with consecutively numbered pages, or on field forms associated with the individual SOPs found in Appendix B of the Work Plan. Field forms for recording various types of sampling and measurement activities include sampling and lithologic logging of solid media. The appropriate field forms are located in the applicable SOP (refer to Appendix B of the Work Plan). The SOPs also provide instructions for recording field activities at the time of field measurements or sample collection.

Field notebook and data sheet entries will, at a minimum, include the information listed below:

- Project name and number;
- Sample location;
- Data and time of sample collection;
- Sample identification numbers;
- Description of sample (sample matrix or species);
- Number of samples collected;
- Field measurements;
- Field observations and weather conditions;
- Personnel present;
- Sampler's signature; and
- Field filtration activities and equipment, if performed.

In addition, other ancillary information shall be recorded, including:

- personnel and/or other visitors to the sampling site(s);
- weather conditions;

- presence of livestock or wild game; and
- any unusual events.

Changes or deletions in the field book or on the data sheets will be recorded with a single strike mark through the changed entry, with the sampler's initials and the date recording the new entry. All entries must remain legible. Sufficient information should be recorded to allow the sampling event to be reconstructed without having to rely on the sampler's memory.

Completed field forms and logbooks will be copied to the project's quality records (refer to Section 2.6.4) in addition to copies of outgoing COCs and sample shipping documents.

### **2.6.2 Chain of Custody Records**

Documentation of sample custody must be maintained. Information on the custody, transfer, handling, and shipping of samples shall be recorded by field personnel on a COC form as specified in SOP No. 2 (Appendix B of the Work Plan), and as described in greater detail in Section 3.2.3 below.

A COC form shall be completed for each set of samples collected daily and shall contain the following information:

- sampler's signature and affiliation;
- program name and identification number;
- date and time of collection;
- sample identification number and matrix;
- analyses requested;
- number of containers;
- signature of persons relinquishing custody, dates, and times;
- signature of persons accepting custody, dates, and times;
- method of shipment; and,
- shipping papers/waybill identification number (as appropriate).

A copy of each as-transmitted COC form shall be retained in the program quality records (refer to Section 2.6.4).

### **2.6.3 Analytical Laboratory Records**

Results received from the laboratory will be documented both in report form and in electronic format. Original hard copy and/or electronic reports and data files received from laboratories will be maintained with the program quality records, as described below. Section 4.0 presents the

project's laboratory reporting requirements in detail. The final deliverable ("data package" or "report") issued to Sunnyside and Formation will include data necessary to complete validation of laboratory results in accordance with specifications included in Section 4.0.

#### **2.6.4 Program Quality Records**

Program quality records are defined as completed, legible documents that furnish objective evidence of the quality of items or services, activities affecting quality, or the completeness and quality of data. These records shall be organized and managed by Formation and shall include, at a minimum:

- copies of all bound field logbooks;
- copies of all field documentation forms;
- field copies and original (laboratory) copies of all COC forms;
- incoming and outgoing program correspondence (letters, telephone conversation records, and e-mail messages);
- copies of all laboratory agreements and amendments thereto;
- as-received laboratory data packages (hard copy and/or electronic);
- complete laboratory data validation packages;
- documentation of field and/or laboratory audit findings and any corrective actions;
- draft and final versions of all monthly and quarterly reports; and,
- draft and final delivered versions of the investigation report(s) and supporting procedures such as statistical analyses, numerical models, etc.

The other documentation included in the program's quality records include the approved Work Plan and QAPP, any approved revisions or addendums to the Work Plan and QAPP, and SOPs referred to for field data collection with any updates, revisions, or addendums to those SOPs approved by the Project Managers and Field Investigations Manager to address specific conditions encountered during the field investigation

### **3.0 DATA GENERATION AND ACQUISITION**

The elements in this section address management of data generation and acquisition activities.

#### **3.1 Sampling Design**

The Work Plan provides a detailed description of the sampling design, including the proposed sample locations, and total numbers of samples needed to complete the investigation. Below is a description of the investigation methods. The SOPs included in Appendix B of the Work Plan provide a more detailed description of those procedures, and they also provide information on field documentation and QA activities for the sampling team.

##### **3.1.1 Core Sampling Locations and Frequencies**

Comprehensive sampling activities, including sampling locations, are summarized in the Work Plan. The number and types of samples that will be collected and sampling locations are detailed in Section 4.0 of the Work Plan.

##### **3.1.2 Core Sampling Methods**

Solid-phase media samples will be collected in accordance with methods specified below. Following sample collection, all equipment will be decontaminated in accordance with the procedures described in SOP No. 7, *Equipment Decontamination* (Appendix B of the Work Plan). Composite samples will be collected using the following methods.

Samples of unconsolidated tailings and alluvium will be collected during borehole advancement. Samples will be collected in a ten-foot core barrel and retained in fresh lexan plastic sleeves in 5-foot intervals. The time of collection will be noted, along with any water or problems associated with recovery of the core. The bag will be labelled as it is brought to the logging station noting the borehole ID, depth, and orientation and of the core, and placed onto a clean sheet of plastic at the logging station. The temperature of the core will be measured with a standard kitchen meat thermometer to determine if the core was heated as a result of the drilling process, as this may affect the potential for collection of microbial samples. Each interval will be photographed.

The color, moisture content, texture, primary and secondary minerals, and biofilm will be noted and logged as described in Section 3.1.3 of this QAPP. If there is a distinct change in biogeochemistry based on this description within the five foot interval, the depth at which the change occurs will be recorded and the interval will be split into separate lexan sleeves so that two individual samples reflecting the distinct geochemical conditions can be collected.

If a particular interval will be sampled for both biology and geochemistry, aseptic protocols must be observed and the biological sample will be collected first to minimize potential for gas exposure and contamination. A sample will be collected from a selected interval in each impoundment for live cultivation for biological analysis, and multiple samples will be collected to represent the range of redox and biofilm conditions that are observed.

#### Geochemical sampling

For each interval to be sampled for geochemistry, a minimum of 1.5 kilos (approximately one quart) of sample will be removed from the upper portion (6 inches of the interval) using a clean and dry steel scoop or trowel. This volume should be confirmed using a scale for the initial samples. For geochemical samples, a fresh gallon sized zip-lock bag will be used to collect this sample. If encountered, oversized (larger than fist sized) clasts will be excluded from this sample.

Samples will be placed into a cooler on ice packs and kept cool (4°C) until shipped to a laboratory where they will be refrigerated until they can be analyzed. Laboratory analyses are described in Section 3.3 of this QAPP and include:

- Multi-element analysis by ICPMS following aqua regia digestion for 34 elements;
- Acid-Base Accounting (ABA), modified Sobek method;
- Net Acid Generation, NAG, to pH 4.5 and 7 end points; and
- Synthetic Precipitation Leaching Procedure (SPLP, EPA Method 1312), followed by analyses of leachate for metals/metalloids by EPA Method 6020.

The mineralogy will be evaluated for a selected subset of these samples, by QEMScan<sup>1</sup> or another suitable method. Samples will be selected for further mineralogical characterization following completion of the other sample analyses and evaluation of those data.

As described in Section 5.2.2 of the Work Plan, the composite samples will be initially screened using the multi-element screening-level analysis, and these results will determine the population profile(s) ultimately used to select a sufficient number of samples to adequately represent each population for the additional analyses.

#### Biological Analysis

The purpose of collecting samples for biological analysis is to preliminarily assess the diversity, abundance, and metabolic capacity of microbes present in the tailings with relevance to future biological treatment closure options. The goal is not to describe the community in detail, but

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<sup>1</sup> Quantitative Evaluation of Minerals by SCANning electron microscopy, a registered trademark owned by FEI Company since 2009.

rather to obtain an initial look at the community under select conditions believed to be potentially important in remediation (e.g., reducing environments, biofilms, etc.). Two types of samples will be collected; live samples, for cultivation, and frozen samples, for molecular (DNA) analysis of microbial community diversity and abundance. The number of biological samples to be collected will be determined based on variability in geochemistry and mineralogy in hand specimen, as well as moisture content, redox conditions, and presence/absence of biofilm. We predict that we will need to collect 4 live, 1 quart samples (one from the base of each tailing impoundment, for example), and 12 frozen samples (3 from each impoundment, reflecting distinct conditions), but the actual number will be determined by site geologists based on variation in the field.

Material will need to be collected aseptically using sterile collection materials. The sampler should wear a fresh pair of alcohol-sanitized nitrile or latex gloves for each sample, and work to minimize cross-contamination due to dust, clothing, hair, etc. If needed, two samplers using “clean hands/dirty hands” techniques can be helpful to avoid touching the sterile scoops or interior of sampling bags or tubes with anything other than the sample.

- Live samples for cultivation will be collected into sterile whirlpak bags using autoclaved (or 10% bleach sterilized, sterile deionized water rinsed stainless-steel scoops). These samples should be collected first, and closed immediately, sealing from the bottom up to remove excess air. Samples will be double-bagged, labelled, and stored unfrozen at 4°C in a cooler for shipment to Enviromin of Bozeman, MT.
- Molecular biology samples will be collected into labelled sterile 50 mL falcon tubes using a sterile scoop. The tube will be immediately sealed with limited head space (but sufficient room to allow for ice expansion if liquids are present) and frozen on dry ice. Samples will be kept frozen until delivered to Enviromin. Shipment protocols to achieve this objective (e.g., double packing, courier protocols) will be provided.

### 3.1.3 Core Logging Methods

The core will be logged in accordance with SOP No. 12, *Drilling and Installation of Shallow Monitoring Wells* (Appendix B of the Work Plan). Lithological and textural descriptions will be noted on a borehole log in accordance with the Unified Soils Classification System (USCS). Core temperature, primary and secondary minerals, and biofilm will also be noted and logged.

### 3.1.4 Groundwater Sampling Methods

Groundwater sampling methods are described in Appendix B (QAPP) of the *Surface Water, Groundwater, and Solid Phase Media Work Plan* (Formation Environmental, 2015).

## 3.2 Sample Handling, Preservation, and Custody

This section describes sample handling requirements and COC procedures from the sample collection step through laboratory analysis and ultimate disposal. Sample custody, packaging, and shipment procedures are described in SOP No. 2, *Sample Custody, Packaging and Shipment* (Appendix B of the Work Plan).

### 3.2.1 Sample Containers, Preservation, and Holding Times

#### Sample Containers

Re-sealable, freezer-type, plastic storage bags (e.g., Ziplock® freezer bags) will be used to contain samples collected from the borehole cores. The mass of material collected for each sample will be sufficient for the laboratory analyses requested, as identified in Table A3-1. After well-mixed sample material has been transferred to the plastic bag, the bag will be sealed and labeled, and then placed into a second, sealable plastic bag to protect the label.

#### Sample Preservation and Storage

The solid-media samples will not require chemical preservation, but they will be maintained at low temperature ( $4^{\circ}\text{C} \pm 2^{\circ}$ ) during storage, handling, and shipping to the laboratory. Sample storage requirements are listed in Table A3-1. Refer to Section 3.1.2 for additional instructions regarding preservation and storage requirements for the samples that are collected for biological analysis.

The equipment rinsate samples will be preserved immediately upon sample collection in order to prevent or minimize chemical changes that could occur during transit and storage. The contracted laboratories will provide containers and appropriate preservatives (i.e., “pre-preserved” containers), as needed for the analyses requested for equipment rinsates.

#### Sample Holding Times

Sample holding times are established to minimize chemical changes in a sample prior to analysis and/or extraction. A holding time is defined as the allowable time between sample collection and analysis recommended to ensure accuracy and representativeness of analysis results, based on the nature of the analyte of interest and chemical stability factors.

Immediately after collection, samples shall be placed in field coolers with wet ice and/or blue ice. If there is no likelihood that a holding time will be violated, samples may be transferred to a locked refrigerator for one or more days of storage prior to shipping to a laboratory. Transfer to the laboratory for analysis should be prompt to minimize the possibility of exceeding holding times.

Holding times for the chemical constituents for which samples will be analyzed are summarized in Table A3-1. Failure to conduct analyses within the required holding times may result in qualification of associated analytical results and shall prompt appropriate corrective and preventive action measures as outlined in Section 4.4.

Refer to Section 3.1.2 for additional instructions regarding the samples that are collected for biological analysis.

### **3.2.2 Sample Handling and Chain of Custody**

#### Sample Handling and Shipping

After collection, sample labels will be completed and the samples will be placed on ice in an insulated cooler. After labeling, each individual sample will be placed in a re-sealable freezer-type plastic storage bag. Each sample container will be carefully packaged in a shipping container, typically an ice chest, with Styrofoam® peanuts or other packing material to prevent breakage during shipment. Ice placed in the cooler will be double-bagged to prevent leakage of water. The coolers will be taped shut and the tape will be placed over the custody seal (see below).

#### Chain of Custody

After samples have been collected, they will be maintained under strict COC protocols. The field sampling personnel will complete a COC form (refer to SOP No. 2, Appendix B of the Work Plan) for each shipping container (i.e., cooler, ice chest or other container) of samples to be delivered to the laboratory for analysis. The sampler is responsible for initiating and filling out the COC form. The COC for a shipping container will list only those samples in that shipping container. Information contained on the triplicate, carbonless COC form will include the following:

- Project number;
- Date and time of collection;
- Sample identification number;
- Sample matrix;
- Analyses requested;
- Number of containers/bags for each sample;
- Sample preservation;
- Field filtration, if applicable;
- Sampler's signature and affiliation;
- Signature of persons relinquishing custody, dates, and times;

- Signature of persons accepting custody, dates, and times;
- Method of shipment;
- Shipping air bill number (if the samples are shipped);
- Condition of samples and cooler temperature upon receipt by laboratory; and
- Any additional instructions to the laboratory.

Any documentation, including COCs, placed inside the cooler during sample shipment, should be placed inside a re-closeable plastic bag.

The sampling personnel whose signature appears on the COC is responsible for the custody of the samples from the time of sample collection until custody of the samples is transferred to a designated laboratory, a courier, or to another project employee for the purpose of transporting the sample to the designated laboratory. The sample is considered to be in custody when the sample is: (1) in the direct possession of the sample custodian; (2) in plain view of the sample custodian or (3) is securely locked in a restricted-access area by the sample custodian. Custody is transferred when both parties to the transfer complete the portion of the COC under "Relinquished by" and "Received by." Signatures, printed names, company names, dates and times are required. Upon transfer of custody, the sampling personnel who relinquished the samples will retain the third sheet (pink copy) of the COC. When the samples are shipped by a common carrier, a Bill of Lading supplied by the carrier will be used to document the sample custody, and its identification number will be entered on the COC. Copies, receipts and carbons of Bills of Lading will be retained as part of the permanent documentation in the project file. It is not necessary for courier personnel to sign the COC.

When the analytical laboratory receives the samples, the COC will be immediately signed along with the date and time of receipt. The top sheet (white copy) or a copy of the COC may be returned with the final analytical report. The laboratory will follow appropriate chain-of-custody procedures when shipping any samples to a subcontracted laboratory for analysis. A copy of all inter-lab COCs will be included with the final analytical report.

#### Laboratory Sample Handling and Storage

Upon receipt by the laboratory, the samples will be inspected for sample integrity and proper preservation, including temperature. The COC will be reviewed to verify completeness. Any discrepancies between the COC and sample labels and any problems or questions noted upon sample receipt will be communicated immediately to the Formation QA Manager. The laboratory shall provide the Formation QA Manager with a copy of the COC, and associated sample-receipt information, within 2 working days of receipt of samples. The sample-receipt information routinely provided will include: sample receipt date, sample IDs transcribed from the COCs, sample matrix type, list of analyses to be performed for each sample, and verification of sample temperatures and preservation requirements. Broken custody seals, damaged sample containers, sample labeling discrepancies between container labels and the COC form, and

analytical request discrepancies shall be noted on the COC form. The Formation QA Manager shall be notified of any such problems; discrepancies or non-conformances shall be resolved and addressed prior to the samples being released to the laboratory for analysis.

The laboratory will store the samples in a specially designated area, which is clean and maintained at the appropriate preservation temperature, if necessary. The laboratory will be responsible for following their internal custody procedures from the time of sample receipt until sample disposal. At a minimum, the following procedures shall also be in place for laboratory storage of samples:

- samples and extracts shall be stored in a secure area controlled by the laboratory's designated sample custodian;
- samples shall be removed from the shipping container and stored in their original containers unless damaged; damaged samples shall be disposed in an appropriate manner after notifying the Formation QA Manager, and authorization to dispose is received and documented;
- whenever samples are removed from storage, removal shall be documented;
- sample transfers shall be documented on internal COC records;
- samples and extracts shall be stored after completion of analyses in accordance with contractual requirements; and
- samples shall not be stored with standards or sample extracts.

### 3.3 Analytical Methods

Samples will be prepared and analyzed using standard laboratory procedures and methods according to performance criteria identified in the following sections. All of the solid samples collected from borehole cores will be analyzed initially for total metals in order to identify any sub-populations of chemically distinct materials in the impoundments. A smaller set of the solid samples will then be identified for the following additional chemical analyses:

- Confirmatory analysis for the TAs;
- Synthetic Precipitation Leaching Procedure(SPLP) for the TAs;
- Acid-base accounting (ABA), including the net acid generating (NAG) potential.

A few of these samples will also be identified for additional tests used to evaluate the metals leaching and metals attenuation potentials. The additional tests will include:

- QEMScan, an electron-microscope analytical procedure, for characterization of mineralogy and mineral surfaces (approximately 5 to 10 samples total); and
- DNA extraction for identification of microbial populations (1 to 2 samples).

As previously discussed, groundwater chemistry and water quality sample analyses are discussed in a separate multi-media SAP/QAPP (Formation Environmental, 2015).

### 3.3.1 Sample Preparation

The laboratory analytical parameters and targeted method detection limits (MDLs) and/or QLs and analytical methods for the laboratory analyses are specified in Table A3-2. A copy of this table will be included in each batch of solid-media samples submitted to the laboratory for analyses to accurately document the analyses being requested.

Sample preparations shall be in accordance with the method specifications included in Table A3-2, as well as standard laboratory practices.

### 3.3.2 Target Analyses and Methods

The target analytes (TAs) for the project include both laboratory and field parameters and are described in detail in Section 4.1 of the Work Plan. Laboratory-analysis parameters are listed in Table A3-2 of this QAPP.

A copy of the appropriate sample-analysis and method table, by sample type, will be included in each batch of samples submitted to the laboratory for analyses to accurately document the analyses being requested.

## 3.4 Quality Control

There is potential variability in any sample collection, analysis, or measurement activity. This section describes checks that will be performed to evaluate that variability.

### 3.4.1 Field Quality Control Samples

Field quality control samples are introduced into the measurement process to provide information on transport, storage and field handling biases and on field sampling precision. Field blank samples and field duplicate samples will be collected. Field blank samples may be identified to the laboratory so that they are not used for preparation of an analytical duplicate or matrix spike sample. Descriptions and frequencies of these QC samples are provided below. Table A3-3 summarizes the minimum required frequencies for the field QC samples.

#### Field Blank Samples

Two types of field blanks will be collected: sterile, quartz sand and equipment rinsate.

The sterile, quartz sand blank will be collected during sampling for biological analyses (Section 3.1.2). One field blank of sterile quartz sand will be submitted to the laboratory to check for biological contamination.

Equipment-rinsate blanks will be collected during all other solid-phase sampling activities. Analyses of equipment rinsates quantify artifacts introduced into the sample during collection. Potential sources of bias or cross-contamination include sampling gloves and sampling equipment that may incidentally come into contact with the sample. An equipment rinsate consists of analyte-free reagent-grade water (e.g., ASTM Type II) poured through the sampling equipment, collected in a clean suite of sample bottles, and preserved as needed. Equipment rinsate samples will be collected at rate of 1 per every 10 field samples (see Table A3-3).

### Field Duplicates

Field duplicates are collected to measure the combined sampling and analytical variability associated with the sample results. Duplicate samples are usually collected simultaneously with or immediately after the corresponding original samples have been collected, depending on the sample type and medium and consistent with detailed instructions in the relevant SOPs for sample collection. In all cases, the same sampling protocol is used to collect the original sample and the field duplicate sample. The field duplicate is analyzed for the same suite of analytical parameters as the original sample.

There are no EPA-recommended criteria for evaluation of field duplicate sample comparability; however, the RPD between the original sample and field duplicate can be calculated for each parameter and compared to the project's precision goal. Analytical data for the field duplicate pairs will be qualified based on the field duplicate RPD results. Field duplicate pairs with RPDs greater than 50% (if sample and duplicate concentrations are  $\geq 5X$  QL) field duplicate pair results will be qualified as estimated ("J" detects and "UJ" for nondetects) and professional judgment will be used regarding flagging other samples in the data set. Possible causes for the observed variability in duplicate samples should be evaluated and explained in the investigation report.

For solid phase media, field duplicates will be collected at a rate of 1 per 10 samples. These samples will be analyzed for the TAs listed in Table A3-3, with the exception of the molecular biology analysis. Given the low number of samples collected for biological analysis, collection and analysis of duplicates is not warranted.

### **3.4.2 Laboratory Quality Control Samples**

Laboratory quality control samples are introduced into the measurement process to evaluate laboratory performance and sample measurement bias. Control samples may be prepared from environmental samples or be generated from standard materials in the laboratory. The appropriate type and frequency of laboratory QC samples will be dependent on the sample matrix, analytical method, and the laboratory's SOP. Laboratory QC samples will be analyzed in addition to the calibration samples with each QC batch.

Table A3-4 summarizes the minimum required frequencies for the laboratory QC samples. A laboratory method blank, laboratory control sample, analytical duplicate, and a pair of matrix spike samples should be run in each laboratory QC batch at a frequency of 1 each per 20 field samples shown in Table A3-4. Field staff responsible for collection and shipping of samples to the laboratory shall designate the samples to be used for laboratory QC analyses on the COC forms. In the event that such instructions are not included, the laboratory shall always utilize samples submitted from the investigation for preparation of laboratory duplicates and matrix spike samples used for batch QC analyses.

#### Method Blanks

Method blanks shall be used for the laboratory processes. A method blank is a volume of deionized water that is carried through the entire sample preparation and analysis procedure. The method blank volume or weight shall be approximately equal to the sample volumes or sample weights being processed. Method blanks are used to monitor interference caused by constituents in solvents and reagents and on glassware and other sampling equipment.

Project target analytes must not be detected in laboratory method blanks at concentrations greater than the QL. Method blank contamination, if found, will be addressed in accordance with the response actions given in Tables A2-2 through A2-4, as appropriate to the analytical methods. Method blanks will be evaluated during the data validation process, and associated sample results may be qualified on the basis of blank contamination.

#### Laboratory Control Samples and Standard Reference Materials

A laboratory control sample (LCS)/laboratory fortified blank (LFB), or a blank spike, is an aqueous or solid control sample of known composition that is analyzed using the same sample preparation, reagents, and analytical methods employed for the program samples. An LCS/LFB is obtained from an outside source or is prepared in the laboratory by spiking reagent water or a clean solid matrix for a stock solution that is different than that used for the calibration standards. The LCS/LFB is the primary indicator of process control used to demonstrate whether the sample preparation and analytical steps are in control, apart from sample matrix effects. LCS/LFB samples will be run with all samples at the frequencies specified herein.

#### Analytical Duplicates

Analytical duplicates are samples that are split at some step in the measurement process and then carried through the remaining steps of the process. Duplicate analyses provide information on the precision of the operations involved.

- Analytical duplicates are a pair of subsamples from a field sample that are taken through the entire preparation and analysis procedure; any difference between the results indicates the precision of the entire method in the given matrix.
- Under certain method protocols (refer to Tables A2-2 through A2-4), the matrix spike is duplicated, to provide a matrix spike duplicate, and serves as the analytical duplicate sample.

Analyses of analytical duplicates and/or matrix spike duplicates monitor the precision of the analytical process.

### Matrix Spikes

A matrix spike is prepared by adding an analyte to a subsample of a field sample before sample preparation and analysis. For multi-analyte methods, a representative suite of the analytes is used in the matrix spike. From the concentrations of the analyte in the spiked and unspiked samples, a percent recovery is calculated. Many samples show matrix effects in which other sample components interfere with the determination of the analyte. The value of the percent recovery indicates the extent of the interference.

Laboratory matrix spike samples are used to evaluate potential sample matrix effects on the accurate quantitation of an analyte using the prescribed analytical method. Percent recoveries of target analytes from matrix spike samples should fall within the prescribed control limits. Matrix interference and other effects may cause low or high percent recoveries in investigative samples; matrix effects may be noted at the same time that recoveries from laboratory control samples indicate acceptable method performance.

Site-specific samples will be used to prepare the MS/MSD samples. Field sampling personnel will collect extra volume and designate on the COC forms the samples that are to be used for the MS/MSD. Every effort will be made to ensure that these samples are representative of the general sample matrix of samples collected on that sampling data. Equipment rinsates are not designated for MS/MSD.

The laboratories will be instructed to use spike concentrations that are consistent with criteria provided in the National Functional Guidelines for Inorganic Data Validation (EPA, 2004) and any specific instructions provided in the referenced analytical methods.

### Performance Evaluation Samples

Program-specific laboratory performance evaluations via performance evaluation samples are not anticipated as part of this investigation, but may be included later if analytical or validation exercises indicate the presence of potential laboratory QA issues.

### **3.5 Instrument/Equipment Calibration and Maintenance**

In order to ensure continual quality performance of any instruments or equipment, calibration and maintenance shall be performed and recorded as described in this section.

#### **3.5.1 Field Equipment**

Preventative maintenance of field equipment will include routine inspection and either calibration or testing as specified in the relevant SOP or manufacturer's instructions.

All field equipment will be cleaned and safely stored between each use, and any routine maintenance recommended by the equipment manufacturer will also be performed. Equipment will be inspected and the calibration checked (if applicable) before it is transported to a field setting for use. Equipment will be inspected before use and field instruments that fail calibration requirements will be tagged as "nonfunctional" or "defective" and returned to the manufacturer or other supplier for repair or replacement.

#### **3.5.2 Laboratory Equipment**

Instruments used by the laboratory will be maintained in accordance with the laboratory's Quality Assurance Plan and method requirements. All analytical measurement instruments and equipment used by the laboratories shall be controlled by a formal calibration and preventive maintenance program. In addition, each laboratory's preventative maintenance program shall include the following, as a minimum:

- a listing of the instruments and equipment;
- the frequency of maintenance considering manufacturer's recommendations and previous experience with the equipment; and
- a file for each instrument containing a list of spare parts maintained, external contracts, and a listing of the items to be checked or serviced during maintenance.

The laboratory will keep maintenance records and make them available for review, if requested, during laboratory audits. Laboratory preventative maintenance will include routine equipment inspection and calibration at the beginning of each day or each analytical batch, per the laboratory's internal SOPs and method requirements.

#### Calibration Methods

Physical and chemical calibrations shall be performed within each laboratory as specified by the EPA Methods, instrument manufacturer's guidelines, and this project's calibration requirements for the requested EPA methods, which are summarized in Tables A2-2 through A2-4. When laboratory measurement instruments do not meet the calibration criteria of the laboratory's Quality Assurance Plan and/or EPA method, then the calibration data will be reviewed using the

National Functional Guidelines (NFGs) (EPA, 2004) and will be qualified accordingly. Calibration records and demonstration of acceptable calibration results will be required elements of the laboratory's data reporting. Records of calibration, repairs, or replacement will be filed and maintained by the designated laboratory personnel performing QC activities. These records will be filed at the location where the work is performed and will be subject to QA audit.

Calibration procedures for a specific laboratory instrument will consist of initial calibration (blank and standards), initial calibration verification (ICV) and continuing calibration verification (CCV). All analyses will be governed by the appropriate laboratory SOPs, and appropriate calibration procedures and frequencies can be found in each SOP.

For a summary of the calibration procedures for individual methods, refer to Tables A2-2 through A2-4. Calibration and quality control sample procedures for trace metals analysis by EPA Method 6010 (inductively coupled plasma [ICP]) are provided in Table A2-2. Calibration and quality control sample procedures for trace metals analysis by EPA Method 6020 (inductively coupled plasma-mass spectrometer [ICPMS]) are provided in Table A2-3. Calibration and quality control sample procedures for mercury by Method 7471 in Table A2-4.

### **3.6 Acceptance Requirements for Supplies and Consumables**

All supplies and consumables received for a project (e.g., sample bottles, calibration standards) will be checked for damage and other deficiencies that would affect their performance. All inspections should be documented and a copy of the inspection should be kept in the project's file.

### **3.7 Criteria for Use of Existing, Non-Direct Measurement Data**

Previous investigations may provide environmental data that are relevant to this investigation. These data are summarized in Section 3.1.7 of the Work Plan and will be used to the fullest extent practicable in the on-going investigation and considering the data quality.

### **3.8 Data Management**

The program quality records will be maintained by Sunnyside's contractor, Formation, in its Boulder, CO office. These records, either electronic or hard copy in form, shall include:

- Project work plans, including this QAPP, with any approved modifications, updates, and addendums;
- Field documentation (including well logs, GPS data on monitoring locations including surveyed elevations of monitoring wells);
- COC records;

- Laboratory documentation (results received from the laboratory will be documented both in report form and in an electronic format);
- Data validation reports;
- Data Summary Reports; and
- Final project reports/deliverables.

Hard-copy field and laboratory records shall be maintained in the project's central data file, where original field and laboratory documents are filed chronologically for future reference. These records are also scanned to produce electronic copies in \*.pdf format. The electronic versions of these records are maintained on Formation's central server system with backup scheduled on a daily basis.

A key element of the project's data management process is maintenance of an electronic database that is used to store relevant environmental sampling data, including existing data considered usable to support the investigation (i.e., non-direct measurement data), in a consistent, readily retrievable format. Microsoft® Access will be used for the data structure and query support, and a designated Database Manager will ensure the security and integrity of electronically stored data. The project's electronic database will be maintained on a central server system with data backup scheduled on a daily basis.

The project database will serve as a source of data for the data presentation and analysis tasks performed to support the hydrogeologic investigation. The database will incorporate, at a minimum, sample collection information (e.g., sample identification, location, date and time of sample collected, matrix) and laboratory analytical fields specified in the project electronic data deliverable (EDD) requirements (Table A3-5).

Prior to incorporation of field and laboratory data into the project database, the data and supporting documentation shall be subject to appropriate review, as described below in Section 4.0, to ensure the accuracy and completeness of original data records. Field data that has been reviewed in a hard-copy format will be entered into electronic data files for upload to the project database. All manual data entry into an electronic format will be reviewed by a separate party before such data are incorporated into the project's database (see Section 4.1). Laboratory EDDs and related data packages will be reviewed as part of the data validation process, as described in Sections 4.2 and 4.4.

Following these review steps, field and laboratory electronic data files will be imported to the project database. The data validator(s) (refer to Section 4.4) will add qualifiers and related information to the EDD file/database, for reference by all data users. The EPA flags, Reason Codes, and final, qualified data will be uploaded from electronic files that the data validators populate and return to Sunnyside/Formation, as discussed in Section 4.0. Standardized data import formats and procedures will be used to upload both field and laboratory data into the electronic database. At this time, standardized station identifiers, parameter names, numerical

formats, and units of measure are applied to the original information to facilitate comparability across all datasets and within the database.

## **4.0 DATA REVIEW, VALIDATION AND USABILITY**

The following sections address the final project checks conducted to confirm that the data obtained meet the project objectives and to estimate the effect of any deviations on data usability.

### **4.1 Field Data Review**

Raw field data shall be entered in field notebooks and/or sample collection record forms. The field records will be reviewed for completeness by the Field Investigations Manager, or his/her designated Field Supervisor, at the end of each day. The overall quality of the field data from any given sampling round shall be further evaluated during the process of data reduction and reporting.

Field data-reduction procedures will be minimal in scope compared to those implemented in the laboratory setting. Field data review will include verification that QC checks are recorded properly in the field logbooks and/or data sheets and that any necessary and appropriate corrective actions were implemented and recorded. Such data will be written into field logbook and/or data sheets immediately after measurements are taken. If errors are made, results will be legibly crossed out, initialed and dated by the field member, and corrected in a space adjacent to the original (erroneous) entry. Later, the appropriate Field Supervisor will proof the field logbooks and/or data sheets to determine whether any transcription errors have been made by the field crew. If transcription errors have been made, the appropriate Field Supervisor and field crew will address the errors to provide resolution.

Field measurement data will be entered into electronic files for import to the project's database. Data entries will be made from the reviewed field data sheets or logbooks, and all data entries will be reviewed by a separate party before the electronic file is provided to the database manager. Electronic files of field measurement data will be maintained as part of the project's quality records.

### **4.2 Laboratory Data Review**

Internal, laboratory data-reduction procedures will be according to the laboratory's Quality Management Plan. At a minimum, paper records shall be maintained by the analysts to document sample identification number and the sample tag number with sample results and other details, such as the analytical method used (SOP #), name of analyst, the date of analysis, matrix sampled, reagent concentrations, instrument settings, and the raw data. These records shall be signed and dated by the analyst. Copies of any strip chart printouts (such as gas chromatograms) will be maintained on file. Periodic review of these records by the laboratory QA Manager takes place prior to final data reporting to Sunnyside.

QC data (e.g., laboratory duplicates, LCS/LFB, MSs, and MSDs) will be compared to the method and project-specific acceptance criteria. Data considered to be acceptable will be entered into the laboratory computer system. Data summaries will be sent to the laboratory QA Officer for review. If approved, data are logged into the project database format. The laboratory shall appropriately flag unacceptable data in the data package.

#### 4.2.1 Laboratory Data Reporting Requirements

The laboratories shall prepare complete data packages for transmittal of results and associated quality control information to Sunnyside and Formation in general accordance with the following instructions, which are based on the EPA's contract laboratory program (CLP) Statement of Work. Deviations from these specifications may be acceptable provided the report presents all of the requested types of information in an organized, consistent, and readily reviewable format. Laboratories providing data packages for this project shall be responsible for reviewing the following requirements, notifying Formation of any differences between their reports and these requirements, and confirming the acceptability of their intended report content and format with Formation before any laboratory data reports are generated for this project.

Each report will be paginated and organized with a table of contents. A cross reference that correlates the client or field identification as provided on the chain-of-custody document with the laboratory's sample identification will be included.

For each batch of sample results consisting of 20 or fewer samples analyzed together and sharing common QC data, the laboratory data will be presented on a form equivalent to the EPA CLP "Form 1" (see below). Case narratives will be prepared which will include information concerning data that fell outside laboratory acceptance limits, and any other anomalous conditions encountered during sample analysis.

CLP Form 1 contains all required data for field samples. The Form 1 (or equivalent reporting mechanism) will provide the following information:

- Field sample identification;
- Laboratory sample identification;
- Sample result, with appropriate units, method detection limit, and QL. [analyte concentrations equal to or greater than the method detection limit (MDL) will be reported. Concentrations between the MDL and QL will be flagged as an estimated value ("J") by the laboratory. Parameters that are not detected or not present at concentrations equal to or greater than the MDL are flagged by the laboratory as "U" and interpreted to be not detected at a value equal to or greater than the MDL. Any non-detected value ("U" flagged) will be reported with its QL and MDL.];
- Sample collection and receipt dates;
- Sample preparation date/time;

- Analysis date/time;
- Dilution factor;
- Preparation batch number or identification;
- Analysis batch number or identification;
- Sample matrix and instrument;
- Percent moisture determination; and
- For solid-matrix samples, identify basis of reporting (i.e., wet-weight or dry-weight basis).

The following additional information will be provided with the Form 1s, as applicable for the reported analytical methods. QC batch will be clearly associated with each sample (on the CLP Form specified, or an equivalent reporting mechanism):

- Case narrative;
- Chain-of-custody;
- Summary of all field sample results (Form 1s, or equivalent, as described above);
- Sample results and preparation blank;
- Initial calibration verification (ICV), and continuing calibration verification (CCV);
- Initial calibration blanks (ICB), continuing calibration blank (CCB), and preparation blanks;
- Low-Level Calibration Check Sample Summary, if necessary
- Inductively coupled plasma (ICP) interference check sample or spectral interference check sample (CLP Form IVA-IN);
- Matrix spike (MS) or analytical spike, and when applicable matrix spike duplicate (MSD) or analytical spike duplicate, sample recovery and, when applicable, MS/MSD relative percent difference (RPD);
- Laboratory duplicate precision, where applicable;
- Laboratory control sample (LCS)/laboratory fortified blnk (LFB) recovery;
- MDLs;
- ICP interelement correction factors;
- ICP and ICPMS linear ranges;
- Preparation log;
- Analysis run Log;
- ICPMS tunes;
- ICPMS internal standards relative intensity summary;
- Sample log-in sheet; and
- Deliverables inventory sheet.

In addition to this standard data package, the laboratory may be requested to deliver a “Level 4” data package, as detailed below. When requested by Sunnyside, the laboratory’s Level 4 Data Package is to include all items specified above plus instrument raw data and/or documentation of the following additional information:

- Calibration standards (including source, preparation date).
- Blanks (ICB, CCB, and preparation).
- ICV, CCV standards.
- Low-Level Calibration Check Sample or Practical Quantitation Verification Standards.
- Interference check samples.
- LCS/LFB.
- Diluted and undiluted samples.
- Dilution factors.
- Sample volumes.
- Laboratory duplicates.
- Matrix spikes (source, concentration, volume).
- Method of standard addition results.
- Instrument identification.
- Analysis date and time.
- All inorganic methods: full raw data printouts from instruments.
- Full run log for each analysis. and
- ICPMS to include: internal standard recoveries, tune data (atomic mass unit [amu] and peak width), and molecular interference check data.

#### **4.2.2 Laboratory Electronic Data Deliverable**

Each data package, as described above, shall be accompanied by an electronic data deliverable (EDD) prepared by the laboratory. The content and format of laboratory EDDs are specified in Table A3-5. Additional laboratory QC data can be included in the EDD as long as the data fields specified in Table A3-5 are also maintained. The last six fields in the table are to be entered by the data validator.

EDDs will be cross checked against corresponding hard-copy data reports to confirm consistency in results reported in these two separate formats. This cross check will take place as part of the data quality review and validation process described in Section 4.4.

### 4.3 Specific Quality Control Assessment Procedures

The accuracy, precision, completeness, and representativeness of analytical data will be described relative to the project's control limits through a process of field and laboratory data quality review and data validation. Results from these reviews will be documented in routine Data Summary Reports prepared for all data users, including the EPA and supporting agencies, and any qualification of the data resulting from that review will also be incorporated into the project's electronic database so that all data users are aware of any uncertainties associated with individual results.

### 4.4 Data Quality Review and Validation

Data validation is the process of verifying that qualitative and quantitative information generated relative to a given sample is complete and accurate. Data validation procedures shall be performed for both field and laboratory operations as described below and in SOP No. 20, *Data Review and Validation* (Appendix B of the Work Plan).

#### 4.4.1 Evaluating Field Data

The results of field quality control sample analyses associated with each laboratory data package will be reviewed to allow for evaluation of equipment blanks and other field QC samples and further indications of the data quality. If a problem is identified through the review of field QC data, all related field samples will be identified, and if possible, corrective actions can be instituted and documented. If data are compromised due to a problem identified via field QC sample review, appropriate data qualifications will be used to identify the data for future data users.

The handling, preservation, and storage of samples collected during the sampling program will be monitored on an on-going basis. The project laboratories will document sample receipt including proper containers and preservation at the time samples are logged into their individual laboratory. The sample receipt records (a required data package deliverable) as well as the COC documentation will also be assessed during data validation. Sample handling, storage or preservation problems identified during data validation will result in appropriate qualification of data.

#### 4.4.2 Evaluating Laboratory Chemistry Data

The purpose of chemistry data validation is to verify that the data are of known quality, technically valid, defensible, and usable for their intended purpose. The objectives of the data review and validation process will be to:

- Verify completeness of data packages and corresponding EDDs;
- Assess compliance to project specific procedures and programs;

- Evaluate system process control through review of control charts (if applicable);
- Verify that no systematic errors exist within the data sets;
- Assess field QC samples to determine if sampling has adversely impacted the reported results and, therefore, usability;
- Assess both method and laboratory performance through tabulation of QC outliers; and
- Provide measures of data quality in terms of precision, accuracy, and completeness so that overall usability can be determined.

Data validation will be performed using the general protocols and processes described in the following documents and in SOP No. 20, *Data Review and Validation* (Appendix B of the Work Plan), as applicable to the method calibration and QC limits specified on Tables A2-2 through A2-4 and to the extent possible when non-CLP methods are used:

- Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (NFG; EPA, 2004); and
- Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use (PEA, 2009).

The data packages will be evaluated and qualified for quantitative QC elements (e.g., spike recoveries, method and field blank contamination, initial and continuing calibration blanks, instrument tunes, interference check samples, duplicate sample %RSD, and instrument stability and performance [e.g., initial and continuing calibration results, instrument tuning and internal standard areas]) using summary forms (described above). This validation procedure is equivalent to a “Stage 2B Validation,” as defined in the EPA guidance for labeling externally validated data (EPA, 2009).<sup>2</sup> Specific QC elements that will be reviewed include:

- Presence and completeness of COC and sample receipt documentation;
- Sample Index (correlation of field sample ID to laboratory sample ID);
- Laboratory Case Narrative (method deviations and QC anomalies);
- Analytical holding times;
- Method blank;
- Matrix spike recoveries;
- Matrix spike/matrix spike duplicate RPD values;
- Field duplicate RPD values;
- Laboratory duplicate RPD values;
- Summaries of initial and continuing calibration;

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<sup>2</sup> EPA, 2009. Page 6: “A verification and validation based on completeness and compliance checks of sample receipt conditions and BOTH sample-related and instrument-related QC results...”

- Summaries of instrument blanks (e.g., initial calibration blank, CCB, if specified in method);
- Review of reagent/preparation blanks (inorganics);
- Review of Laboratory Control Standards (LCS);
- Instrument stability and performance (e.g., serial dilution);
- Summaries of internal standards;
- Completeness of laboratory documentation for sample receipt, sample analysis, and sample result reporting;
- Interference check samples (ICP analysis); and
- Serial dilutions (ICP analysis), if any.

Formation will indicate data qualifiers applied to individual results and reasons for application of those qualifiers. Definitions of the data qualifiers that may be applied to individual results as a result of data validation are as follows:

- |    |  |
|----|--|
| U  | The analyte was analyzed for, but was not detected above the level of the reported sample QL.  |
| J  | The result is an estimated quantity. The associated numerical value is the approximated concentration of the analyte in the sample.  |
| J+ | The result is an estimated quantity, but the result may be biased high.  |
| J- | The result is an estimated quantity, but the result may be biased low.   |
| R  | The result is unuseable. The sample result is rejected due to serious deficiencies in meeting quality control criteria. The analyte may or may not be present in the sample. |
| UJ | The analyte was analyzed for, but was not detected. The reported QL is approximate and may be inaccurate or imprecise.   |

Formation will add the following data to that EDD upon completion of validation:

Field Header "Validation Qualifier": Populate with validation qualifiers specified above and in template reports.

Field Header "Validation Qual Reason": Populate with a specific reason for qualification if EPA codes are not used.

Field Header "Val Status": Populate with a code to indicate if the data has been validated or not.

Field Header "Val Person": Populate with a code to specify the validation contractor and validator.

Field Header "Val Protocol": Populate with a code to refer to for validation procedures (QAPP or NFG, etc.) used.

Field Header "Val Notes": Populate with additional information that is specific to a sample.

Formation will perform a Manual Validation, as defined in the EPA guidance for labeling externally validated data (EPA, 2009), on the data packages generated by the laboratories.

#### **4.5 Data Usability**

Laboratory packages summarizing the data generated for this investigation will be validated as described above. Once validated, the data will be loaded into a project database managed by Formation. Data usability will be determined by Formation based on the results of data validation and overall comparison to DQOs.

#### **4.6 Measurement Data Analysis and Reporting**

Measurement data will be reported in consistent units for each sample matrix to maintain comparability and facilitate data analyses. Concentrations in liquid samples shall be expressed in terms of weight per unit volume such as milligram per liter (mg/L). The number of significant figures in the field and laboratory data presented in the final report shall be consistent with the limits of uncertainty inherent in the measurement or analytical method.

Statistical analyses and other evaluations may be performed that consider the validated data set. The original detected values for parameters with results below the minimum QL may be used as appropriate to the selected statistical methods. Statistical methods may include published methods found in statistical handbooks, textbooks, and EPA or other agency statistical guidance documents.

## 5.0 ASSESSMENT AND OVERSIGHT

Assessments of data collection and reporting activities are designed to verify that sampling and analyses are performed in accordance with the procedures established in the Work Plan and QAPP. The audits of field and laboratory activities include two independent parts: internal and external audits. Internal audits will be performed by Sunnyside, Formation, or a contracted laboratory. External audits may be performed by the Lead Agency or supporting agencies. Procedures used to conduct internal and external audits shall be consistent with those described in *EPA Guidance on Technical Audits and Related Assessments* (EPA QA/G-7; EPA, 2000).

Performance and systems audits of field and laboratory data collection and reporting procedures are described in this section. Data assessments, such as data verification and validation, were presented in Section 4.0.

### 5.1 Field Performance and System Audits

Formation's QA Manager, or designee, may conduct an onsite systems and performance audit of field sampling practices at any time during the field data collection activities. Any non-conformances observed in the audit shall be documented and resolved. Additional systems audits or surveillance may be conducted during the remaining field investigations at the discretion of the Formation Project Manager or Formation QA Manager. One field audit per field season is recommended but not required.

#### 5.1.1 Internal Field Audits

Internal audits of field activities, including sampling and field measurements, will be conducted by the Formation QA Manager or designee. These audits will verify that procedures established in the Work Plan and QAPP, including referenced SOPs (Appendix B of the Work Plan), are being followed.

The internal field audits (systems and performance audits) will include examination of field measurement and sampling records and field instrument operating records; sample collection, handling, decontamination, and packaging activities; and documentation of sampling activities in compliance with the established procedures for each field activity audited. Follow-up audits may be conducted to correct deficiencies, and to verify that QA procedures are maintained throughout the investigation. The results of field audits will be documented. The completed field audit report will be kept on file by the Formation QA Manager. After a field audit is conducted, the results of the audit will be shared by the auditor with the field teams prior to additional sampling to enhance sampling performance where applicable.

Findings of these audits will be summarized in an audit report that is given to the Formation Project Manager, Field Investigations Manager, and appropriate Field Supervisor in charge of the audited activities. The audited party will submit a reply addressing each finding cited in the report, the corrective action (if necessary) to be taken, and a schedule for implementation. The Field Investigations Manager is responsible for ensuring that corrective actions are taken.

### **5.1.2 External Field Audits**

External field audits may be conducted by representatives from the Agencies. External field audits may be conducted at any time during the field operations. These audits may or may not be announced and are at the discretion of the Agencies.

External field audits will be conducted according to the field activity information presented in the field SOPs or in the sampling procedures outlined in the Work Plan. Results of the external field audit may document the need for a change to procedures in the Work Plan and/or QAPP and result in the need for an amendment to the Work Plan and/or QAPP.

## **5.2 Laboratory Performance and Systems Audits**

### **5.2.1 Internal Laboratory Audits**

The internal laboratory audit will be conducted by the QA Officer at each laboratory utilized for the investigation. Audits will be performed in accordance with the laboratory's Quality Management Plan.

The internal laboratory system audits will be conducted on an annual basis while the internal lab performance audits will be conducted on a quarterly basis, or as specified in the laboratory's Quality Management Plan.

The internal laboratory system audits will include an examination of laboratory documentation on sample receiving, sample log-in, sample storage, COC procedures, sample preparation and analysis, instrument operating records, etc. The performance audits will involve preparing blind QC samples and submitting them along with project samples to the laboratory for analysis throughout the project. The QA Officer from each laboratory utilized for this investigation will evaluate the analytical results of these blind performance samples to ensure the laboratory maintains acceptable QC performance.

### **5.2.2 External Laboratory Audits**

An external laboratory audit may be conducted by representatives from the Agencies at any time. An external laboratory audit may be conducted prior to the initiation of the sampling and

analysis activities. These audits may or may not be announced, may be conducted at any time and are at the discretion of the Agencies.

External laboratory audits will include (but not be limited to) review of laboratory analytical procedures, laboratory on-site audits, and/or submission of performance evaluation samples to the laboratory for analysis. Typically, the external laboratory audit will be conducted in the lab so that the staff may be questioned regarding laboratory procedure. A recently produced sample data package will be compared with their SOP to ensure compliance with applicable standards.

### 5.3 Corrective Actions

Corrective action is the process of identifying, recommending, approving, and implementing measures to counter unacceptable procedures or out-of-QC performance, which can affect data quality. Corrective action can occur during field activities, laboratory analyses, data validation and data assessment.

Non-conforming equipment, items, activities, conditions and unusual incidents that could affect data quality and attainment of the project's quality objectives will be identified, controlled and reported in a timely manner. For the purpose of this QAPP, a nonconformance is defined as a malfunction, failure, deficiency, or deviation that renders the quality of an item unacceptable or indeterminate in meeting the project's quality objectives.

Corrective action in the laboratory may occur prior to, during and after initial analyses. If the analytical results from laboratory QC samples fall outside of the measurement performance criteria, the laboratory should initiate corrective actions immediately. If the laboratory cannot correct the situation that caused the nonconformance and an out-of-control situation continues to occur or is expected to occur, then the laboratory will immediately contact the Formation QA Manager and request instructions regarding how to proceed with sample analyses. A number of conditions such as broken sample containers, multiple phases, low/high pH readings and potentially high concentration samples may be identified during sample log-in or just prior to analysis. Following consultation with lab analysts and section leaders, it may be necessary for the Laboratory Project Manager (or designated QA Officer) to approve the implementation of corrective action. These conditions may include dilution of samples, additional sample extract cleanup, automatic re-injection/re-analysis when certain QC criteria are not met, etc.

Completion of any corrective action should be evidenced by data once again falling within prescribed measurement performance criteria. If an error in laboratory procedures or sample collection and handling procedures cannot be found, the results will be reviewed by the Formation QA Manager and Formation Project Manager to assess whether reanalysis or re-sampling is required.

Any corrective actions taken will be documented in writing by either the Laboratory Project Manager (or designated QA Officer) or the Formation QA Manager, as appropriate, and

reported to the Formation Project Manager. Corrective action records will be included in the program's quality records.

#### **5.4 Corrective Action during Data Validation and Data Assessment**

The Formation QA Manager may identify the need for corrective action during either the data validation or later data assessment/analysis. Potential types of corrective action may include re-sampling by the field team, reanalysis of samples by the laboratory, or re-submission of data packages with corrected clerical errors. The appropriate and feasible corrective actions are dependent upon the ability to mobilize the field team and whether the data to be collected is necessary to meet the required QA objectives (e.g., the holding time for samples is not exceeded, etc.). Corrective actions of this type will be documented by the Formation QA Manager.

#### **5.5 Quality Assurance Reports to Management**

The deliverables associated with the tasks identified in the Work Plan will contain QA discussions of data quality information collected during the task is summarized. Those reports will be the responsibility of the Formation Project Manager and QA Manager.

The QA discussions will contain, on a routine basis, the results of field and laboratory audits, information generated on the achievement of specific DQOs and a summary of any corrective actions that were implemented and their immediate results on the project. Detailed references to any QAPP modifications will also be highlighted.

## 6.0 QAPP REFERENCES

EPA, 2001. Requirements for Quality Assurance Project Plans, EPA QA/R-5.

EPA, 2000. Guidance on Technical Audits and Related Assessments, EPA QA/G-7.

EPA, 2002. Guidance for Quality Assurance Project Plans EPA QA/G-5. EPA 240-R-02-009. December.

EPA, 2004. EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review. EPA 540-R-04-004. October.

EPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4, EPA/240/B-06/001. February.

EPA, 2009. EPA Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use. EPA 540-R-08-005. January.

Formation Environmental, 2015. Surface Water, Groundwater, and Solid Phase Media Investigation Work Plan, Mayflower Mill and Tailings Impoundments Area. Dated July.

## QUALITY ASSURANCE PROJECT PLAN

### TABLES

Table A2-1

## Precision, Accuracy and Completeness Calculation Equations

Characteristic	Formula	Symbols
<b>Precision</b> (as relative percent difference, RPD)	$RPD = \frac{ x_i - x_j }{\frac{x_i + x_j}{2}} \times 100$	$x_i, x_j$ : replicate values of $x$
<b>Precision</b> (as relative standard deviation, RSD, otherwise known as coefficient of variation)	$RSD = \frac{s}{\bar{x}} \times 100$	$s$ : sample standard deviation $\bar{x}$ : sample mean
<b>Accuracy</b> (as percent recovery, R, for samples without a background level of the analyte, such as reference materials, laboratory control samples, and performance evaluation samples)	$R = \frac{x}{t} \times 100$	$x$ : sample value $t$ : true or assumed value
<b>Accuracy</b> (as percent recovery, R, for measurements in which a known amount of analyte, a spike, is added to an environmental sample)	$R = \frac{x_s - x}{t} \times 100$	$x_s$ : value of spiked sample $x$ : value of unspiked sample $t$ : true or assumed value
<b>Completeness</b> (as a percentage, C)	$C = \frac{n}{N} \times 100$	$n$ : number of valid data points produced $N$ : total number of samples taken

Table A2-2

## Summary of Calibration and QC Procedures for EPA Method 6020 (ICPMS)

Quality Control Check	Minimum Frequency	Lab Acceptance Criteria	Corrective Action/Lab Flagging Criteria
Sample preservation and holding time	Not applicable	Sample holding time is 180 days for aqueous samples preserved to pH < 2 with nitric acid.	Laboratory will note sample condition on receipt and notify client if criteria are not met.
AMU Check Tune	Prior to initial calibration solution as specified by lab's standard operating procedure (SOP).	Mass calibration < 0.1 amu from the true value; Stability: RSD < 5% for at least five replicate analyses. Peak resolution < 0.75 AMU at 5% peak height.	Retune instrument then reanalyze tuning solution.
Initial calibration (ICAL) for all target analytes (minimum one standard and a blank)	Daily initial calibration prior to sample analysis.	Calibration blank plus 4 non-zero standards. ICAL must be repeated for each batch unless CCV is used for continuing calibration. If the correlation coefficient for the element of interest is not greater than 0.995, then the instrument must be recalibrated and all of the associated samples for that element must be reanalyzed.	Correct problem then repeat initial calibration.
Initial Calibration Verification (ICV)	Immediately after ICAL, before beginning a sample run and from a second source.	All analytes within $\pm 10\%$ of expected value.	Rerun ICV. If that fails, correct problem and repeat ICAL.
Initial Calibration Blank (ICB)	Immediately after ICV.	< 2.2X the Method Detection Limit (MDL) for dissolved 200.8 analyses or < 3X the MDL of the associated analyte.	Recalibrate if ICB is outside of acceptance criteria. Reanalyze all associated samples that are < 10X the blank and > zero since the last compliant CCB.
Continuing Calibration Verification (CCV)	After every 10 samples and at the end of the analysis sequence.	The analyte concentration within $\pm 10\%$ of expected value	Correct problem then repeat CCV and reanalyze all samples since last successful CCV. If CCV recovery was high, "U" samples can be qualified and passed.
Continuing Calibration Blank (CCB)	Immediately after ICB, after every 10 samples, and at the end of the analytical sequence (after every 20 samples for dissolved analyses)	< 3X MDL	Correct problem then reanalyze calibration blank and previous 10 samples. Reanalyze all associated samples that are < 10X the blank and > zero since the last compliant CCB.
Laboratory Reagent Blank	One per analytical batch of 20 or fewer samples of the same matrix	< 2.2X MDL	Correct problem and reanalyze. Recalibrate if ICB is outside of acceptance criteria.
Laboratory Fortified Blank (LFB)	One LFB per analytical batch of 20 or fewer samples	85-115%	Correct problem then reanalyze. If still out, re-prepare and reanalyze the LFB and all samples in the preparation batch. If the LFB recovery is high, "U" samples may be qualified and passed.
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	One MS/MSD per every 10 samples per matrix - not to be performed using a field blank.	Percent recovery should be within $\pm 30\%$ and Relative Percent Difference (RPD) should be < 20%. If sample is spiked post digestion, percent recovery should be $\pm 15\%$ . MS/MSD recoveries are not applicable if the sample concentration is >4x the spike concentration.	Qualify associated sample results
Field duplicate sample	1 field duplicate per every 10 samples per matrix	Not applicable	Not applicable
Internal Standards (IS)	Every sample; internal standards as specified by method and lab's SOP.	60% - 125% of intensity in the calibration blank.	Dilute by a factor of two and re-analyze. If IS recoveries still out, report undiluted results.
Concentrations between the MDL and CRQL	All samples	Not applicable	Qualify to indicate value is between MDL and QL.

Note that specific QC procedures may vary based on the laboratory that performs the analyses.

AMU - Atomic Mass Unit

MDL - Method detection limit

QL - Quantitation Limit. May be referred to as "PQL" - Practical Quantitation Limit or "RL" - Reporting Limit.

ppb - parts per billion

RSD - Relative Standard Deviation

Table A2-3

## Summary of Calibration and QC Procedures for EPA Method 6010 (ICP)

Quality Control Check	Minimum Frequency	Lab Acceptance Criteria	Corrective Action/Lab Flagging Criteria
Sample preservation and holding time	Not applicable	Sample holding time is 180 days for aqueous samples preserved to pH $\leq 2$ with nitric acid.	Laboratory will note sample condition on receipt and notify client if criteria are not met.
Initial calibration (ICAL) for all target analytes (minimum one standard and a blank)	Daily initial calibration prior to sample analysis	Calibration blank plus 1 or more non-zero standards. When 3 or more points are used, the criteria is $r^2 > 0.995$ .	Correct problem then repeat initial calibration.
Initial Calibration Verification (ICV)	After ICAL, before beginning a sample run (at a concentration other than used for calibration and from a second source)	All analytes within $\pm 5\%$ of expected value. When 3 or more points are used, the criteria is $r^2 > 0.995$ .	Correct problem and verify second source standard. Rerun ICV. If that fails, correct problem and repeat ICAL.
Initial Calibration Blank (ICB)	After ICV	$< 3X$ Method Detection Limit (MDL)	Correct problem and reanalyze. Sample values $> 10X$ ICB may be accepted and qualified if ICB fails high.
Practical Quantitation Verification (PQV)	Daily, after ICAL and before samples are run.	The analyte concentrations within $\pm 30\%$ of expected value.	Correct problem then reanalyze.
Spectral Interference Check Sample	Immediately after PQV.	Recovery must be within $\pm 20\%$ of expected value.	Correct problem and reanalyze.
Continuing Calibration Verification (CCV)	After every 10 samples and at the end of the analysis sequence (at a mid-calibration range concentration).	The analyte within $\pm 10\%$ of expected value	Correct problem then repeat CCV and reanalyze all samples since last successful CCV. Samples $< MDL$ may be accepted and qualified if CCV fails high.
Continuing Calibration Blank (CCB)	Immediately after CCV and after every 10 samples, and at end of the analytical sequence.	$< 3X$ MDL	Correct problem then reanalyze calibration blank and previous 10 samples. Sample values $> 10X$ CCB or $< MDL$ may be accepted and qualified if CCB fails high.
Laboratory Reagent Blank (LRB) / Method Blank	One per analytical batch of 20 or fewer samples of the same matrix.	$< 2.2X$ MDL	Correct problem and reanalyze. Samples values $> 10X$ LRB or $< MDL$ may be accepted and qualified if LRB fails high.
Laboratory Fortified Blank (LFB)/Laboratory Control Sample (LCS)	One LFB per analytical batch of 20 or fewer samples	85-115%	Correct problem then reanalyze. If still out, re-prepare and reanalyze the LFB and all samples in the preparation batch. If LFB fails high, samples $< MDL$ may be accepted and appropriately qualified.
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	One MS/MSD per every 10 samples per matrix - field blanks may not be used.	Percent recovery should be within $\pm 30\%$ and Relative Percent Difference (RPD) should be $< 20\%$ . If sample is spiked post digestion, percent recovery should be $\pm 15\%$ . MS/MSD recoveries are not applicable if the sample concentration (used for spiking) is $> 4x$ the spike concentration.	Flag associated sample results. If the $RPD \geq 20\%$ samples must be re-prepped and reanalyzed. Ag must have passing RPD in digested samples.
Field duplicate sample	1 field duplicate per every 10 samples per matrix	Not applicable	Not applicable
Concentrations between the MDL and CRQL	All samples	Not applicable	Qualify to indicate value is between MDL and QL.

Note that specific QC procedures may vary based on the laboratory that performs the analyses.

MDL - Method detection limit

QL - Quantitation Limit. May be referred to as "PQL" - Practical Quantitation Limit or "RL" - Reporting Limit.

TABLE A2-4

## Summary of Calibration and QC Procedures for EPA Method 7471A (Mercury by CVAA)

Quality Control Check	Minimum Frequency	Lab Acceptance Criteria	Corrective Action/Lab Flagging Criteria
Initial calibration (ICAL) for all target analytes (minimum five standards including a blank)	Daily initial calibration prior to sample analysis	Blank plus 4 or more calibration concentrations, correlation coefficient ( $r$ ) $\geq 0.995$	Correct problem then repeat initial calibration.
Initial Calibration Verification (ICV)	After ICAL, before beginning a sample run (at a concentration other than used for calibration and from a	All analytes within $\pm 20\%$ of expected value	Correct problem and verify second source standard. Rerun ICV. If that fails, correct problem and repeat ICAL.
Initial Calibration Blank (ICB)	After ICV	Absolute value $\leq 2 \times \text{MDL}$ for each analyte. If $(2 \times \text{MDL}) > \text{QL}$ , then use the absolute value $\leq \text{QL}$ as the criteria instead.	Correct problem and reanalyze.
CRQL Check Standard (CRI)	Daily, after ICAL, after every 20 samples and at end of each analysis run.	Within $\pm 30\%$ of expected value.	Correct problem then reanalyze.
Continuing Calibration Verification (CCV)	After every 10 samples and at the end of the analysis sequence (at a mid-calibration range concentration)	The analyte within $\pm 20\%$ of expected value	Correct problem then repeat CCV and reanalyze all samples since last successful CCV.
Continuing Calibration Blank (CCB)	Before beginning a sample run, after every 10 samples, and at end of the analytical sequence	Absolute value $\leq 2 \times \text{MDL}$ for each analyte. If $(2 \times \text{MDL}) > \text{CRQL}$ , then use the absolute value $\leq \text{CRQL}$ as the criteria	Correct problem then reanalyze calibration blank and previous 10 samples.
Method Blank (or preparation blank)	One per analytical batch	Absolute value $\leq \text{CRQL}$	If absolute value is $> \text{QL}$ all sample results (excluding field blanks) must be $\geq 10 \times$ the blank concentration. Otherwise, all samples associated with the blank and $< 10 \times$ blank concentration must be redigested and reanalyzed.
LCS	One LCS per analytical batch (1/20 samples).	Aqueous LCS: 80-120% or vendor-specified or laboratory-determined control limits (but not wider than 80-120% recovery). Solid LCS/SRM: vendor-specified control limits.	Correct problem then reanalyze. If still out, re-prepare and reanalyze the LCS/SRM and all samples in the preparation batch.
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	One MS/MSD per every 20 samples per matrix - field blanks may not be used.	Laboratory-determined control limits (but not wider than 75-125% recovery and $\text{RPD} < 20$ ). MS/MSD recoveries are not applicable if the sample concentration (used for spiking) is $> 4 \times$ the spike concentration.	Flag associated sample results and perform post-digestion spike.
Analytical duplicate sample	One duplicate per every 20	$\text{RPD} < 20\%$ if sample and	Flag associated sample results.
Field duplicate sample	1 field duplicate per every 10 samples per matrix	Not applicable	Not applicable

Note that specific QC procedures may vary based on the laboratory that performs the analyses.

MDL - Method detection limit

QL - Quantitation Limit. May be referred to as "PQL" - Practical Quantitation Limit or "RL" - Reporting Limit.

**Table A3-1**

**Sample-Mass, Containers, Preservation, and Holding-Time Specifications for Analyses of Solid-Media Samples**

Sample Type	Analytes	Analysis Methods	Sample Mass Needed for Analysis	Sample Preparation Method	Number and Type of Containers	Preservation	EPA Recommended Holding Time (days)
Solid	Total Metals Screening-Level Analysis	ICP-MS	10 grams	Aqua Regia digestion	Plastic bag	Cool to 4°C ± 2°	not defined
Solid	Total Metals Confirmatory Analysis	6010 6020	10 grams	Method 3050B Hot plate/acid digestion	Plastic bag	Cool to 4°C ± 2°	180
Solid	Total Metals Confirmatory Analysis	7471	10 grams	Preparation per Method 7471A	Plastic bag	Cool to 4°C ± 2°	28
Solid	Fluoride (soluble)	ASTM D 3761	25 grams	Aqueous extraction	Plastic bag	None	not defined
Solid	SPLP	1312/6020	100 grams	Method 1312	Plastic bag	Cool to 4°C ± 2°	180
Solid	ABA and NGP	Refer to Table A3-2	10 grams	M600/2-78-054	Plastic bag	Cool to 4°C ± 2°	not defined
Solid	Archive for possible future analyses	TBD	1000 grams	TBD	Plastic bag or core liner/sleeve	Store at <25° C	not defined
Solid - Live Culture	DNA Extraction and Microbiological Analysis	Refer to QAPP Section 3.1.2	1500 grams	--	Whirlpak bag	Cool to 4°C ± 2°	not defined
Solid - Frozen			fill 50 mL falcon tube	--	50 mL Falcon Tube	Freeze	

**Table A3-2**

**Laboratory Methods and Detection Limits for Target Analytes in Solid-Media Samples**

Target Analyte	EPA Method Number	Method Detection Limit (MDL) <sup>1</sup> (mg/kg)	Quantitation Limit (QL) <sup>1</sup> (mg/kg)
Aluminum	6010	3	15
Antimony	6020	0.2	1
Arsenic	6020	0.1	0.5
Barium	6010	0.3	1.5
Beryllium	6010	1	5
Cadmium	6010	0.5	2.5
Calcium	6010	10	50
Chromium	6020	0.25	1.25
Cobalt	6010	1	5
Copper	6010	1	5
Iron	6010	2	10
Lead	6010	3	15
Lithium	6010	0.8	4
Magnesium	6010	20	100
Manganese	6010	0.5	2.5
Mercury	7471	0.0002	0.001
Molybdenum	6010	2	10
Nickel	6010	0.8	4
Selenium	6020	0.05	0.25
Silica	6010	42.8	214
Silver	6010	1	5
Strontium	6010	0.5	2.5
Thallium	6020	0.05	0.25
Vanadium	6020	0.1	0.5
Zinc	6010	1	5
<b>Other</b>			
Fluoride (soluble)	ASTM D 3761	0.1	0.5
SPLP <sup>2</sup> extraction and analysis for metals listed above	1312/6020 <sup>3</sup>	--	--
Acid-Base Accounting (ABA)	600/2-78-054	--	--
Total Element Analysis (above metals)	IMS 12B	--	--
Net Acid Generation (NAG)	VOL <sup>4</sup>	--	--
DNA Extraction for Molecular Biology	See Note 5	--	--

**Notes:**

1. Targeted MDLs and QLs are listed. Laboratories routinely adjust these values, and therefore, reported MDLs and QLs may differ slightly from those listed here.
2. SPLP = Synthetic Precipitation Leaching Procedure
3. Multi-element analysis by ICP-MS following aqua regia digestion.
4. pH 4.5 to 7 end points
5. DNA extraction followed by illumina sequencing and data reduction.

**Table A3-3**

**Required Frequencies for Field Quality Control Samples**

Sample Type	Analytes	Analysis Methods	Field Duplicate	Equipment Rinsate Blank <sup>1</sup>	Sterile Sand Blank <sup>2</sup>	Identify Sample to Lab for Use in Preparation of Matrix Spike Samples
Solid	Metals and Metalloids (Table 3-2)	6010 6020 7471	1/10 samples	1/10 samples	NA	1/20 samples
Solid	DNA Extraction and Microbiological Analysis	Refer to QAPP Section 3.1.2	NA	1 equipment rinsate blank per sampling event	1 per sampling event	NA

**Table A3-4**

**Required Frequencies for Laboratory QC Analyses**

Sample Type	Analytes	Analysis Methods	Method Blank	Laboratory Fortified Blank/Laboratory Control Sample	Analytical Duplicate	Matrix Spike/Matrix Spike Duplicate Pair
Solid	Metals and Metalloids (Table 3-2)	6010 6020 7471	1/20	1/20	1/20	1 pair/ 20 samples

NA - Not Applicable

**Table A3-5**

**EDD Specifications for the Laboratory**

Lab EDD Fields	Description
COCSSampleID	Field sample Identification number
SampleDate	Date sample collected
SampleTime	Time sample collected
PreparationMethod	Preparation method number
AnalyticalMethod	Analytical method number
Matrix	Sampling matrix
TorDAnalysis	Total or dissolved analysis (filtered or unfiltered sample)
Basis	Wet/dry basis for analyte reporting
Analyte	Parameter label
Result	Measured concentration
Units	Units of measure
DetLimit	Detection limit
DetLimitType	Detection limit type (e.g., MDL or IDL)
ReportingLimit	Reporting limit
LabQualifier	Parameter value qualifier
Dilution	Dilution factor
LabName	Lab name
SDGNumber	Lab Sample Delivery Group (SDG) number
LabSampleID	Lab sample identification number
ReceivedDate	Date sample received by laboratory
AnalysisDate	Data sample analyzed by laboratory
QQualifier	EPA qualifier (e.g., H or D)
CAS#	Compound name
Validation Qualifier <sup>1</sup>	Qualifier applied based on data validation (J+, UJ, etc)
Validation Qual Reason <sup>1</sup>	If EPA codes not used, a written explanation of the reason qualified
Val Status <sup>1</sup>	Explains if the data has been validated or not
Val Person <sup>1</sup>	Validation contractor and validator (initials)
Val Protocol <sup>1</sup>	Document validator referred to for validation procedures (QAPP or NFG, etc.)
Val Notes <sup>1</sup>	Additional information pertaining to a result

EDD - Electronic data deliverable

IDL - Instrument detection limit

MDL - Method detection limit

SDG - Sample delivery group

<sup>1</sup> Fields to be added by Validator

## Appendix B – Standard Operating Procedures (SOPs)

### LIST OF SOPS

<u>SOP No.</u>	<u>Title</u>
1	Field Documentation
2	Sample Custody, Packaging and Shipment
7	Equipment Decontamination
8	Monitoring Well Development
12	Drilling and Installation of Monitoring Wells
20	Data Review and Validation

## **SOP No. 1 Field Documentation**

## **STANDARD OPERATING PROCEDURE No. 1**

### **FIELD DOCUMENTATION**

#### **1.0 SCOPE AND APPLICABILITY**

The following Standard Operating Procedure (SOP) describes the protocol for documenting field monitoring activities. The procedures presented herein are intended to be general in nature and are applicable when referenced by site-specific or project-specific planning documents. Appropriate modifications to the procedures may be made to accommodate project-specific protocols when approved in writing or via email by the Project Manager or detailed in a project work plan, sampling plan, or quality assurance project plan.

The objective of this SOP is to establish a consistent method and format to document daily field activities. The resultant field notes and records are intended to provide sufficient information that can be used to recreate the field activities and the collection of environmental data.

#### **2.0 BASIS FOR METHODOLOGY**

The methods and procedures described in this SOP were developed from these sources:

- ☐ ANSI/ASQC E-4 (1994) American National Standards Institute/American Society for Quality Control Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs.
- ☐ ASTM D 6089 (2010) American Society for Testing and Materials (ASTM) ASTM D 6089 Standard Guide for Documenting a Ground-Water Sampling Event.
- ☐ EPA QA/G6 (2007) U.S. Environmental Protection Agency Guidance for Preparation of Standard Operating Procedures (SOPs). EPA/600/B-07/001. Office of Environmental Information, Washington, DC, April.
- ☐ EPA QA/G5 (2002) U.S. Environmental Protection Agency EPA Guidance for Quality Assurance Project Plans. EPA/240/R-02/009. Office of Environmental Information, Washington, DC, December.

### **3.0 PROCEDURES**

#### **3.1 Daily Field Activities**

The field representative actually performing the environmental monitoring or sampling will record all field activities in the field notebook for each day of field work.

Documentation will include:

- A. Project identification;
- B. Date;
- C. Time on job (beginning and ending time);
- D. Weather conditions;
- E. Activity description;
- F. List of personnel and visitors on site;
- G. Safety equipment used and monitoring performed;
- H. Waste storage inventory (if any);
- I. Chronological record of activities and events;
- J. Comments and variances from project work plan;
- K. Content of telephone conversations;
- L. Calibration parameters; and
- M. Signature of the field representative.

The field representative will document all details that would be necessary to recreate the day's activities and events at a later time. The field notebook will be used to document field activities and information that may not be specified on other field record forms. Other activity-specific documentation requirements to be recorded on field record forms are discussed in the Standard Operating Procedure for each activity.

## **4.0 DOCUMENTATION**

### **4.1 Field Record Forms**

In addition to the field notebook, field personnel will complete specific field record forms (which may be in paper or electronic format) applicable to the field activities being conducted. The procedures for completion of activity-specific field record forms are presented in the applicable Standard Operating Procedures. Additional field record forms and applicable procedures may be created for project-specific activities, as necessary.

### **4.2 Records Management**

All original field forms and copies of field notebooks will be filed with the appropriate project records in the project files. Specific field record forms filled out using an electronic device will be printed and filed with the appropriate project records.

## **5.0 QUALITY ASSURANCE/QUALITY CONTROL**

All completed field forms will be reviewed by the Project Manager or project-designated reviewer. Any necessary corrections will be made in pen with a single-line strike out that is initialed and dated.

## **6.0 REFERENCES**

American National Standards Institute/American Society for Quality Control, 1994. Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs. ANSI/ASQC E-4.

American Society for Testing and Materials (ASTM), 2010. ASTM D 6089-97. Standard Guide for Documenting a Ground-Water Sampling Event. American Society for Testing and Materials available online at <http://www.astm.org/>

U.S. Environmental Protection Agency (USEPA), 2007. EPA QA/G6, Guidance for Preparing Standard Operating Procedures (SOPs). EPA/600/B-07/001. Office of Environmental Information, Washington, DC, April. Available online at <http://www.epa.gov/QUALITY/qs-docs/g6-final.pdf>

U.S. Environmental Protection Agency (USEPA), 2002. EPA QA/G5, EPA Guidance for Quality Assurance Project Plans. EPA/240/R-02/009. Office of Environmental

Information, Washington, DC., December.  
<http://www.epa.gov/QUALITY/qs-docs/q5-final.pdf>

Available online at

## **SOP No. 2 Sample Custody, Packaging and Shipment**

## **STANDARD OPERATING PROCEDURE No. 2**

### **SAMPLE CUSTODY, PACKAGING, AND SHIPMENT**

#### **1.0 SCOPE AND APPLICABILITY**

The following Standard Operating Procedure (SOP) describes the protocol for sample custody and packaging and shipment of samples. The procedures presented herein are intended to be general in nature and are applicable when referenced by site-specific or project-specific planning documents. Appropriate modifications to the procedures may be made when approved in writing or via email by the Project Manager.

This SOP applies to any liquid or solid sample that is being transported by the sampler, a courier, or an overnight delivery service.

#### **2.0 BASIS FOR METHODOLOGY**

The methods and procedures described in this SOP were developed from these sources:

- ☐ 49 CFR 173. Shippers – Shippers – General Requirements for Shipping. United States Code of Federal Regulations available online at <http://www.gpoaccess.gov/cfr/index.html>
- ☐ 49 CFR 178. Specifications for Packaging. United States Code of Federal Regulations available online at <http://www.gpoaccess.gov/cfr/index.html>
- ☐ ASTM D 4220-95 (2000). Standard Practices for Preserving and Transporting Soil Samples, American Society for Testing and Materials available online at <http://www.astm.org/>
- ☐ ASTM D 4840-99 (2010). Standard Guide for Sampling Chain-of-Custody Procedures. American Society for Testing and Materials available online at <http://www.astm.org/>

### **3.0 PROCEDURES**

The objectives of this packaging and shipping SOP are to minimize the potential for sample breakage, leakage, or cross contamination; to provide for preservation at the proper temperature; and to provide a clear record of sample custody from collection to analysis.

#### **3.1 Packaging Materials**

The following is a list of materials that will be needed to facilitate proper sample packaging:

- ☐ Chain-of-Custody (COC)/Request for Analysis (RA) forms;
- ☐ Analyte List;
- ☐ Coolers (insulated ice chests) or other shipping containers as appropriate to sample type;
- ☐ Transparent packaging tape;
- ☐ Duct tape or similar (for sealing cooler drain);
- ☐ Zip-lock type bags (note: this is used as a generic bag type, not a specific brand name);
- ☐ Large garbage bags;
- ☐ Protective wrapping and packaging material;
- ☐ Contained ice (packaged and sealed to prevent leakage when melted) or "Blue Ice"; and
- ☐ Chain-of-Custody seals.

#### **3.2 Sample Custody from Field Collection to Laboratory**

After samples have been collected, they will be maintained under chain-of-custody procedures. These procedures are used to document the transfer of custody of the samples from the field to the designated analytical laboratory. The same chain-of-custody procedures will be used for the transfer of samples from one laboratory to another, if required.

The field sampling personnel will complete a COC/RA form and provide an Analyte List for each separate container of samples to be shipped or delivered to the laboratory for chemical or physical (geotechnical) analysis. Information contained on the form will include:

1. Project identification;
2. Date and time of sampling;
3. Sample identification;
4. Sample matrix type;
5. Sample preservation method(s);
6. Number and types of sample containers;
7. Sample hazards (if any);
8. Requested analysis(es);
9. Method of shipment;
10. Carrier/waybill number (if any);
11. Signature of sampling personnel;
12. Name of Project Manager;
13. Signature, name and company of the person relinquishing and the person receiving the samples when custody is being transferred;
14. Date and time of sample custody transfer;
15. Condition of samples upon receipt by laboratory; and
16. Chain of Custody identification number.

The samples will be carefully packaged into shipping containers/ice chests.

The sampling personnel whose signature appears on the COC/RA form is responsible for the custody of a sample from the time of sample collection until the custody of the sample is transferred to a designated laboratory, a courier, or to another employee for the purpose of transporting a sample to the designated laboratory. A sample is

considered to be in their custody when the custodian: (1) has direct possession of it; (2) has plain view of it; or (3) has securely locked it in a restricted access area.

Custody is transferred when both parties to the transfer complete the portion of the COC/RA form under "Relinquished by" and "Received by." Signatures, printed names, company or organization names, and date and time of custody transfer are required. Upon transfer of custody, the sampling personnel who relinquished the samples will retain a copy of the COC/RA form.

### **3.3 Sample Custody within Laboratory**

The designated laboratory will assume sample custody upon receipt of the samples and COC/RA form. Sample custody within the analytical laboratory will be the responsibility of designated laboratory personnel. The laboratory will document the transfer of sample custody and receipt by the laboratory by signing the correct portion of the COC/RA form. Upon receipt, the laboratory sample custodian will note the condition of the samples, by checking the following items:

1. Agreement of the number, identification and description of samples received by comparison with the information on the COC/RA form; and
2. Condition of samples (any bottle breakage; leakage, cooler temperature, etc.).

If any problems are discovered, the laboratory sample custodian will note this information on the "Laboratory Comments/Condition of Samples" section of the COC/RA form, and will notify the sampling personnel or Project Manager immediately. The Project Manager will decide on the final disposition of the problem samples.

The laboratory will retain a copy of the COC/RA form and return an electronic copy to the originator with the final laboratory report of analytical results. The original of the COC/RA form will be retained as part of the permanent documentation in the project file. A record of the history of the sample within the laboratory containing sample status and storage location information will be maintained in a logbook, or a computer sample tracking system, at the laboratory. The following information will be recorded for every sample access event:

1. Sample identification;
2. Place of storage;
3. Date(s) and time(s) of sample removal and return to storage;
4. Accessor's name and title;
5. Reason for access; and
6. Comments/observations (if any).

The laboratory will provide a copy of the logbook or computer file information pertaining to a sample upon request.

### **3.4 Sample Custody during Inter-Laboratory Transfer**

If samples must be transferred from one laboratory to another, the same sample custody procedures described above will be followed. The designated laboratory person (sample custodian) will complete a COC/RA form and sign as the originator. The laboratory relinquishing the sample custody will retain a copy of the completed form. The laboratory receiving sample custody will sign the form, indicating transfer of custody, retain a copy, and return the original record to the originator with the final laboratory report of analytical results. The COC/RA form will be retained as part of the permanent documentation in the project file.

### **3.5 Packaging and Shipping Procedure**

All sample containers will be properly labeled and all samples will be logged on the COC/RA form in accordance with the procedures explained.

All samples will be packed in the cooler so as to minimize the possibility of breakage, cross-contamination, and leakage. Before placing the sample containers into the cooler, all sample bottle caps will be checked and tightened if necessary. A large garbage bag will be placed as a liner inside the cooler and duct tape (or similar) will be used to seal off any drain openings on the inside and/or outside of the cooler. Bottles made of breakable material (e.g., glass) will also be wrapped in protective material (e.g., bubble wrap, plastic gridding, or foam) prior to placement in the cooler. Each sample set or soil

tube liner (for a California, Shelby Tube or Split-spoon Sampler) will be placed into a zip-lock bag to protect from cross-contamination and to keep the sample labels dry. Sample containers will be placed upright in the cooler. Stacking glass sample bottles directly on top of each other will be avoided.

If required by the method, samples will be preserved to 4°C prior to the analysis. Water ice or “blue ice” will be used to keep the sample temperatures at 4°C. The ice will be placed in two zip-lock bags if the samples are to be transported by someone other than the sampler (e.g., a courier or overnight delivery service). The zip-lock bags of ice will be placed in between, on the bottom, and/or on top of the sample containers so as to maximize the contact between the containers and the bagged ice. If the sampler is transporting the samples to the laboratory shortly after sample collection, the water ice may be poured over and between the sample bottles in the cooler.

If there is any remaining space at the top of the cooler, packing material (e.g., Styrofoam pellets or bubble wrap) will be placed to fill the open space of the cooler. After filling the cooler, the garbage bag will be sealed, a copy of the COC/RA form and Analyte List will be placed in a zip-lock bag and taped to the inside of the cooler lid, the top of the cooler will be closed, and the cooler will be shaken to verify that the contents are secure. Additional packaging material will be added if necessary.

When transport to the laboratory by the sampler is not feasible, sample shipment will occur via courier or overnight express shipping service that guarantees shipment tracking and next morning delivery (e.g., Federal Express Priority Overnight or UPS Next Day Air). The same procedures will be followed to pack and fill the cooler and provide the COC/RA form and Analyte List, as if the sampler were transporting the samples to the laboratory. The cooler will be taped shut with packaging tape. Packaging tape will completely encircle the cooler, and chain-of-custody seals will be signed and placed across the front and side of the container opening.

Copies of all shipment records provided by the courier or overnight delivery service will be retained and maintained in the project file.

#### **4.0 DOCUMENTATION AND RECORDS MANAGEMENT**

Daily Field Records or a field notebook with field notes will be kept describing the packaging procedures and the method of shipment. Copies of all shipping records and chain-of-custody records will be retained in the project file.

#### **5.0 QUALITY ASSURANCE**

The Project Manager or designated reviewer will check and verify that documentation has been completed and filed per this procedure.

#### **6.0 REFERENCES**

49 CFR 173. Shippers – General Requirements for Shipments and Packagings. United States Code of Federal Regulations. Available online at <http://www.gpoaccess.gov/cfr/index.html>

49 CFR 178. Specifications for Packaging. United States Code of Federal Regulations. Available online at <http://www.gpoaccess.gov/cfr/index.html>

ASTM D 4220-95 (2000). Standard Practices for Preserving and Transporting Soil Samples, ASTM International, West Conshohocken, PA, 2000. Available online at <http://www.astm.org/>

ASTM D 4840-99 (2010). Standard Guide for Sampling Chain-of-Custody Procedures, ASTM International, West Conshohocken, PA, 2010. Available online at <http://www.astm.org/>

## **SOP No. 7 Equipment Decontamination**

## **STANDARD OPERATING PROCEDURE No. 7**

### **EQUIPMENT DECONTAMINATION**

#### **1.0 SCOPE AND APPLICABILITY**

This Standard Operating Procedure (SOP) describes the methods to be used for decontamination of all reusable field equipment that could become contaminated during use and/or sampling. Field equipment may include split spoons, reusable bailers, trowels, scissors, shovels, hand augers, or any other type of equipment used during field activities. Decontamination is performed as a quality assurance measure and a safety precaution; it prevents cross contamination between samples and also helps to maintain a clean working environment. The procedures presented herein are intended to be general in nature and are applicable when referenced by site-specific or project-specific planning documents. Appropriate revisions may be made to accommodate site-specific conditions or project-specific protocols when approved in writing or via email by the Project Manager.

Decontamination is achieved primarily by rinsing with liquids which may include: soap and/or detergent solutions, potable water, distilled weak acid solution, and/or methanol or other solvent. Equipment may be allowed to air dry after being cleaned or may be wiped dry with chemical-free towels or paper towels if immediate re-use is necessary.

At most project sites, decontamination of equipment that is re-used between sampling locations will be accomplished between each sample collection point. Waste produced by decontamination procedures, including waste liquids, solids, rags, gloves, etc., should be collected and disposed of properly, based upon the nature of contamination. Specific details for the handling of decontamination wastes are addressed in SOP No. 3 (STORAGE AND DISPOSAL OF SOIL, DRILLING FLUIDS, AND WATER GENERATED DURING FIELD WORK) or may be specified by a project plan.

## **2.0 BASIS FOR METHODOLOGY**

The methods and procedures described in this SOP were developed from these sources:

- ASTM D5088. Standard Practice for Decontamination of Field Equipment Used at Waste Sites. American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2008.
- Parker and Ranney, 1997a. Decontaminating Ground Water Sampling Devices, CRREL Special Report 97-25, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.
- Parker and Ranney, 1997b. Decontaminating Materials Used in Ground Water Sampling Devices, CRREL Special Report 97-24, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.

## **3.0 PROCEDURES**

### **3.1 Responsibilities**

It is the responsibility of the field sampling supervisor to ensure that proper decontamination procedures are followed and that all waste materials produced by decontamination are properly managed. It is the responsibility of the project safety officer to draft and enforce safety measures that provide the best protection for all persons involved directly with sampling and/or decontamination.

It is the responsibility of any subcontractors (e.g., drilling contractors) to follow the proper, designated decontamination procedures that are stated in their contracts and outlined in the Site-Specific Health and Safety Plan. It is the responsibility of all personnel involved with sample collection or decontamination to maintain a clean working environment and ensure that any contaminants are not negligently introduced to the environment.

### 3.2 Supporting Materials

Materials needed for equipment decontamination include:

- ☐ Cleaning liquids: laboratory grade soap and/or detergent solutions (Alconox, etc.), potable water, distilled water, methanol, weak nitric acid solution, etc.
- ☐ Personal protective safety gear as defined in the Site-Specific Health and Safety Plan
- ☐ Chemical-free towels or paper towels
- ☐ Disposable nitrile gloves
- ☐ Waste storage containers: drums, boxes, plastic bags, etc.
- ☐ Cleaning containers: plastic and/or stainless steel pans and buckets
- ☐ Cleaning brushes
- ☐ Aluminum foil

### 3.3 Methods

The extent of known contamination will determine the degree of decontamination required. If the extent of contamination cannot be readily determined, cleaning should be done according to the assumption that the equipment is highly contaminated. Decontamination procedures should account for the types of contaminants known or suspected to be present. In general, high levels of organic contaminants should include an organic solvent wash step, and high levels of metals contamination should include a weak acid rinse step.

The procedures listed below constitute the full field decontamination procedure. If different or more elaborate procedures are required for a specific project, they may be specified in the project planning documents. Such variations in decontamination protocols may include all, part, or an expanded scope of the decontamination procedure stated herein.

1. Remove gross contamination from the equipment by dry brushing, and rinse with potable water.
2. Wash with laboratory-grade detergent solution.

3. Rinse with potable water.
4. Rinse with methanol (optional, for equipment potentially contaminated by organic compounds).
5. Rinse with acid solution (optional, for equipment potentially contaminated by metals).
6. Rinse with distilled or deionized water.
7. Repeat entire procedure or any parts of the procedure as necessary.
8. Air dry.

#### **4.0 DOCUMENTATION**

Field notes will be kept describing the decontamination procedures followed. The field notes will be recorded according to procedures described in SOP No. 1 (FIELD DOCUMENTATION).

#### **5.0 QUALITY CONTROL**

To assess the adequacy of decontamination procedures, field rinsate blanks may be required. The specific number of field rinsate blanks will be defined in the project-specific Sampling and Analysis Plan (SAP) or Quality Assurance Project Plan (QAPP).

Rinsate blanks with elevated or detected contaminants will be evaluated by the Project Manager, who will relay the results to the field personnel. Such results may be indicative of inadequate decontamination procedures that require corrective actions (e.g., retraining).

#### **6.0 REFERENCES**

ASTM D5088-02 (2008). Standard Practice for Decontamination of Field Equipment Used at Waste Sites. American Society for Testing and Materials (ASTM) International, West Conshohocken, PA, 2008. Available online at <http://www.astm.org/>

Parker and Ranney, 1997a. Decontaminating Ground Water Sampling Devices, CRREL Special Report 97-25, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.

Parker and Ranney, 1997b. Decontaminating Materials Used in Ground Water Sampling Devices, CRREL Special Report 97-24, U.S. Army Engineer Cold Regions Research and Engineering Laboratory, Hanover, NH.

## **SOP No. 8 Monitoring Well Development**

## **STANDARD OPERATING PROCEDURE No. 8**

### **MONITORING WELL DEVELOPMENT**

#### **1.0 SCOPE AND APPLICABILITY**

This Standard Operating Procedure (SOP) describes the protocol to be followed during the development of groundwater monitoring wells. Monitoring wells must be developed before they are used to collect groundwater samples. The procedures presented are intended to be general in nature. As site-specific conditions become known, appropriate modifications of the procedures may be made and will be documented in the well development field log.

#### **2.0 BASIS FOR METHODOLOGY**

The methods and procedures described in this SOP were developed from these sources:

- ☐ ASTM D5521-05. Standard Guide for Development of Groundwater in Granular Aquifers. American Society for Testing and Materials available online at <http://www.astm.org>.
- ☐ SESD, 2008. Design and Installation of Monitoring Wells, SESDGUID-101-R0.
- ☐ USACE, 1998. Engineering and Design – Monitoring Well Design, Installation, and Documentation at Hazardous Toxic, and Radioactive Waste Sites, EM 1110-4000, Washington, DC.
- ☐ USEPA and NWWA, 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA 160014-891034.

### **3.0 PROCEDURES**

#### **3.1 Development Procedure**

After construction of the monitoring well is complete, the well will be developed by air lifting, surging, bailing and/or pumping (e.g., positive displacement hand pump, electric pump or pneumatic pump). At least 24 hours must pass between completion of grouting of the monitoring well and development to allow sufficient curing of the grout.

The total depth of the well will be measured with a weighted tape. The presence of sediment at the bottom of the well will be checked using a stainless steel bailer or positive displacement hand pump. Water and sediment will first be removed from the bottom of the well to ensure that the entire screened interval is open for water to flow into the well. The well should be bailed or pumped until the water removed from the bottom of the well is relatively free of sediment. If a bailer is used, care must be taken to avoid breaking the bottom cap on the well casing.

After most of the sediment has been removed from the bottom of the well, a well development pump (positive displacement hand pump, electric pump or pneumatic pump) should be used to remove water from the well. Initially, the intake of the pump should be at the bottom of the well. The pump intake should be raised in two- to three-foot increments to the top of the water column after approximately one-half of a casing volume of water has been removed from each interval.

Next, a surge block constructed of non-reactive material (usually stainless steel or PVC) should be used to develop the well screen by forcing water in and out of the screened area. The surge block should be moved up and down in one-to two-foot increments creating a suction action on the upstroke and a pressure action on the downstroke. Development should begin at the top of the water column and move progressively downward to prevent the surge block from

becoming sand locked. After surging to the bottom of the well, the surge block should be moved progressively upward to the top of the water column. Jetting with water from an approved source may also be used as an alternative method to develop the well.

If necessary, water may be added to the well to facilitate surging. This water should be distilled deionized or "clean" potable municipal water. The volume of de-ionized water added to the well should be noted on the Well Development Record form (attached).

After surging, the surge block should be removed and replaced with the pump or bailer. The intake of the pump or bailer should be at the bottom of the well to remove any sediment that may have collected in the bottom of the well. The pump intake should again be raised in two- to three-foot increments to the top of the water column after approximately one-half of a casing volume of water has been removed from each interval.

During development, the pH, specific conductance and temperature of the purge water should be periodically measured and documented on a Well Development Record form (attached). Parameter readings should be collected and noted for every casing volume of water removed from the well.

The well should be alternately surged and pumped until the field water quality parameters have stabilized to within 10% for specific conductance, 0.05 pH units for pH, and 1°C for temperature, and the water is relatively clear and free of sediment.

Water removed during well development should be directed to an appropriate sediment basin located on the leased property. Final disposal of all water generated during development procedures will be conducted in accordance with all legal requirements.

### **3.2 Documentation and Records Management**

A Well Development Record will be filled out for each well developed. Also, the daily events and other items not covered in the Well Development Record will be entered on a Daily Field Record.

## **4.0 QUALITY ASSURANCE/QUALITY CONTROL**

### **4.1 Equipment Cleaning**

All reusable equipment used in developing the monitoring well should be cleaned prior to and following use. Cleaning shall be accomplished by either (1) washing with a laboratory-grade detergent/water solution, rinsing with clean, potable, municipal water, then rinsing with distilled or deionized water; or (2) steam cleaning followed by rinsing with distilled or deionized water. An acid rinse (0.1 N HCl) or solvent rinse (i.e., hexane or methanol) may be used to supplement these cleaning steps if tarry or oily deposits are encountered. The acid or solvent rinse will be followed by thoroughly rinsing with water. After final cleaning, equipment will be packaged and sealed in plastic bags or other appropriate containers to minimize contact with dust or other contaminant when not in use.

### **4.2 Records Review**

The Project Manager or designated QA reviewer will check and verify that documentation has been completed and filed per this procedure.

**FORMATION****ENVIRONMENTAL**2500 55<sup>th</sup> Street, Suite 200  
Boulder, Colorado 80301

Project Name:

Project No.:

**WELL DEVELOPMENT SUMMARY**  
**WELL \_\_\_\_\_**

Page 1 of 2

Developed by: ..... Development Method and Equipment: .....

Surging: .....

Monitored by: ..... Bailing: .....

Pumping: .....

Date Started: ..... Other: .....

Date Completed: ..... Decontamination: .....

.....

**MONITORING EQUIPMENT**Instruments:Calibration:

Field or Factory

Date

Standards

Type

Model

Serial No.

Water Level Indicator

pH

Conductivity

Temperature

Turbidity

**WELL MEASUREMENTS**Prior to Development:

Date and Time: . . . . .

Water Level (ft):

Well Depth (ft):

Floating Phase Y N Thickness (ft):

Sinking Phase Y N Thickness (ft):

Meas. Reference and Height above Ground Surface (ft)

Following Development:

Date and Time: . . . . .

Water Level (ft):

Well Depth (ft):

Floating Phase Y N Thickness (ft):

Sinking Phase Y N Thickness (ft):

Meas. Reference and Height above Ground Surface (ft)

**PURGE VOLUME INFORMATION**

A. Casing I.D. (in)

B. Casing Unit Volume (gal) [B = A<sup>2</sup> x 0.0408]

C. Well Depth (ft)

D. Water Level (ft)

E. Length of Water in Casing (ft) [E = C - D]

F. Casing Water Volume (gal) [F = E x B]

G. Casing Volumes Required

H. Required Removal Volume (gal) [H = G x F]

Project #: .....

## Page 2 of 2

Notes:

## **SOP No. 12 Drilling and Installation of Shallow Monitoring Wells**

## **STANDARD OPERATING PROCEDURE No. 12**

### **DRILLING AND INSTALLATION OF SHALLOW MONITORING WELLS**

#### **1.0 SCOPE AND APPLICABILITY**

This Standard Operating Procedure (SOP) describes the protocol to be followed during drilling and installation of shallow monitoring wells.

The procedures presented herein are intended to be general in nature. As site-specific conditions become known, appropriate modifications of the procedures may be made when approved in writing by the Project Manager.

#### **2.0 PROCEDURES**

This SOP addresses shallow monitoring wells (collectively referred to herein as wells) to be constructed to with a single well casing generally intersecting the water table. The following subsections provide a general summary of monitoring well design and construction techniques. The actual design, installation, development, and abandonment of any monitoring well will be documented in the Site records.

##### **2.1 Equipment**

The following lists the equipment anticipated to be needed for well installation:

- ☐ Schedule 40 PVC well casing and screen materials (of appropriate diameter, length and slot size as specified in the work plan);
- ☐ Medium bentonite chip for annular seal;
- ☐ Filter pack (appropriately sized unless otherwise indicated);
- ☐ Cement and powdered bentonite for grouting (sulfate-resistant Portland Cement Type V, if appropriate);
- ☐ Stainless-steel centralizers (depending on well installation method);
- ☐ Protective surface casing with lockable steel cap;
- ☐ Steel or concrete guard posts;

- ☐ High-pressure steam cleaner;
- ☐ Long-handled bristle brushes;
- ☐ Wash/rinse tubs;
- ☐ Alconox detergent;
- ☐ Location map;
- ☐ Drill rig capable of installing wells to the desired depth in the expected formation materials and conditions;
- ☐ Sealable bags or chip boxes;
- ☐ Self-adhesive labels;
- ☐ Deionized water;
- ☐ Appropriate health and safety equipment;
- ☐ Daily drilling summary forms;
- ☐ Drilling log forms; and
- ☐ Well installation report forms.

## **2.2 Drilling Procedures**

The drilling process will minimally alter subsurface conditions, and proper assurances will be in place to prevent the drilling process from introducing foreign substances into the borehole or creating conduits that facilitate the spread of existing contaminants.

### **2.2.1 Drilling Techniques**

Wells typically installed using this SOP will be less than 150 feet deep and consist of single wells with screens intersecting the water table. The typical drilling methods appropriate for installing wells at these depths include:

- ☐ Down hole hammer (most appropriate for very hard to hard rock types, but depth may be limited by hydrostatic pressures)
- ☐ Rotary drilling with air, water or foam (most appropriate for hard to soft rock, mud may be needed in unconsolidated formations)
- ☐ Direct push (unconsolidated materials)

Discussion of these drilling methods are given in "Groundwater and Wells" by Driscoll, 1986; Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells" EPA, March 1991 (EPA/600/4-89/034); "RCRA Ground-Water Monitoring, Technical Guidance" EPA; and "Geoprobe Dual Tube Soil Sampling System" Geoprobe Systems. Specialized methods may be combined with the drilling methods

listed above, such as casing advancement while drilling (e.g., ODEX or TUBEX method), or reverse circulation. The method chosen for shallow well installation will depend largely on factors such as relative cost, sample reliability, availability, Site accessibility, and ability to reach desired depths.

For any site or drilling location, the selection of drilling methods will be based on: (1) availability and cost of the method; (2) suitability for the type of geologic materials at the site (e.g., consolidated, unconsolidated); and (3) potential effects on sample integrity (influence by drilling fluids and potential for cross contamination between aquifers). Drill bit (hole) size shall be sufficient to permit efficient installation of the specified well materials. Any drilling fluids needed, will be used in accordance with manufacturer's specifications.

### **2.2.2 Decontamination**

At contaminated sites, equipment will need to be decontaminated. Drilling equipment will be decontaminated prior to arrival on site. Drill bits, the downhole hammer and drill strings will be decontaminated between boreholes. Heavy equipment, depending on the extent of contamination and the cleaning requirements, will be decontaminated at each sampling and/or excavation site or at the designated decontamination area. Sampling equipment (California tubes, stainless-steel or brass liners, bailers, etc.) will be decontaminated between sampling points to minimize potential cross-contamination. Coring equipment will be decontaminated between holes. All drilling equipment will be decontaminated at the conclusion of well installation, prior to leaving the site. Decontamination will be completed according to SOP entitled Equipment Decontamination. Drilling foam may be used to facilitate drilling and will be properly contained per SOP entitled Storage and Disposal of Soil, Drilling Fluids, and Water Generated during Field Work. All well materials (i.e., casing, screen, centralizers) will be decontaminated by steam cleaning prior to installation except materials that can be certified clean (e.g., new materials in original packaging).

### **2.3 Borehole Logging**

Borehole geology will be logged by examination of the drill cutting samples or core samples according to American Society for Testing and Materials (2000), *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*, ASTM D

2488-90, Vol. 04.08, 320-329. If coring is not conducted, the drill cuttings should be logged considering the lag time associated with depth of drilling.

All boreholes shall be continuously logged to ensure stratigraphic control by an experienced geologist. Samples should be collected at all suspected changes in lithology and from the screened interval. All confining layer intervals should be classified and the nature of the contacts documented. The data will be recorded on a borehole drilling log form or similar (attached), and will include the following information:

- ☐ Project name and number;
- ☐ Geologist's or engineer's name;
- ☐ Borehole number and location;
- ☐ Surface elevation (if available);
- ☐ Drilling company and driller's name;
- ☐ Date drilling started and finished;
- ☐ Drilling equipment and method;
- ☐ Drill bit type and size;
- ☐ Total borehole depth;
- ☐ Sample depths and times;
- ☐ Geologic conditions with depth, such as lithology, texture, structure, bedding, color, alteration, mineralization, gouge zones, moisture content, and the Unified Soil Classification (if in unconsolidated materials);
- ☐ Core data;
- ☐ Hydrogeologic conditions with depth, such as water producing zones, flow rates, pH, specific conductance, and fluid description;
- ☐ Presence and/or frequency of fractures;
- ☐ Water levels;
- ☐ Lost circulation zones; and
- ☐ Drilling observations.

## **2.4 Monitoring Well Installation**

Shallow monitoring wells will consist of a single well casing within one borehole. Each shallow monitoring well will be designed to intersect the water table and to permit groundwater sampling of that interface. Separate monitoring wells may be completed, as necessary, in the different water-yielding zones underlying the site (see SOP entitled, Drilling and Installation of Deep Multi-Level Monitoring Wells). The field geologist, in consultation with the Project Manager, will specify the exact depths of screened intervals

using the lithologic log and geophysical log (if performed) for control. Construction and completion of all monitoring wells will be in general conformance with the following procedures.

#### **2.4.1 Well Screens and Riser Casing**

Each well casing shall extend at least 24 inches above ground surface to facilitate groundwater sampling. The inside diameter of both the well screen and casing will be sufficiently large to permit easy passage of all in-well gauging, development, and sampling equipment, typically two-inch inside diameter casings are satisfactory. The monitoring well assembly shall consist of flush joint, threaded casing composed of polyvinyl chloride (PVC) Schedule 40 (minimum) able to withstand the physical forces expected. The threaded joints will have O-ring seals.

Well screens will consist of 0.020-in factory continuous slot or similar size, depending on geologic conditions, with a maximum length of 15 feet for the shallow interval intersecting the water table

Prior to well construction, the field geologist will inspect the blank and slotted casing delivered to the job site to verify that it meets the project specifications. When the total depth of a boring has been reached, and prior to installation of the well casing, the field geologist will measure and record the depth to water in the borehole.

Upon completion of drilling and/or geophysical logging, the monitoring well casing and screen will be assembled and lowered to the bottom of the boring. The monitoring well assembly will be designed so that the well screen is approximately adjacent to the water-yielding zone that is to be monitored. The bottom of the screen will be approximately flush with the bottom of the well and will be closed with a threaded PVC cap or plug, or a slip cap secured with stainless steel screws. No PVC cement or other solvents are permitted to be used to fasten the joints of the casing or screen. Centralizers spaced at the top and bottom of the screened interval may be used to center the well assembly in the borehole, unless the boring is drilled by a low annular space method and the well is installed with the drill casing in place. Wells installed prior to pulling low annular space drill casing will be centered by the inside walls of the drill casing.

If well casing assembly is being performed by a drilling subcontractor, the field geologist

will observe and inspect the assembly, insuring that the bottom cap is threaded or secured with stainless steel screws, O-rings are properly placed in the joints, the joints are completely tightened, and the blank and screen intervals are constructed as specified. The field geologist will measure the location of the top and bottom of the perforated interval by measuring the distances from the joint above the perforated interval to the top slot and from the base of the bottom cap to the bottom slot.

If a mud rotary drilling technique is used and the monitoring well assembly has been lowered to the specified depth, clean water may be circulated downward through the well casing and upward through the annular space between the borehole wall and the monitoring well casing. Circulation will continue until the suspended sediment in the return fluid has been thinned. If the well is greater than 50 feet deep, the casing assembly will be held under tension prior to and during emplacement of the filter pack and seal.

#### **2.4.2 Filter Pack**

The annular space between the borehole wall and the screen will be filled with clean filter pack material. Filter pack material will be well-graded, clean sand with less than 2 percent by weight passing a No. 200 sieve and less than 5 percent by weight of calcareous material. At least two inches of filter pack material shall be installed between the well screen and the borehole wall. Filter pack will likely be 8-12 mesh silica sand (0.093-0.055 in), or 10-20 Colorado Silica Sand, although the possibility of using a different mesh sizes appropriately matched to the screen slot size remains.

The filter pack shall be installed in a manner that prevents bridging and particle-size segregation. Filter sand will be tremied into the annular space using a one-inch diameter (or larger) pipe, in a calculated quantity sufficient to fill the annular space to a level of about ten feet above the top of the screen interval. For wells shallower than about 50 feet, the filter pack can be installed by gravity pouring. The filter pack will be added to a minimum of 2 feet above the top of the screen to a maximum of 5 feet. The depth to top of filter pack will be measured with a weighted tape after each lift.

### **2.4.3 Annular Well Seal**

The well casing shall be sealed to prevent possible preferential downward pathways from the surface to the saturated zone. Once the depth to the top of the filter pack has been verified the remaining open annulus will be backfilled using of medium bentonite chip (1/4-in to 3/8-in). The bentonite seal will be placed to approximately 5 feet below ground surface. Annular materials will be placed as advance casing or hollow stem augers are removed from the borehole.

### **2.4.4 Surface Completion and Capping**

Upon completion of the annular seal, a suitable protective casing with lockable lid will be placed around the well casing. The protective casing will extend to a minimum depth of 2 feet below the ground surface. The upper 5 feet of the borehole annulus will be backfilled with concrete. A concrete surface pad measuring 4 feet square and 6 inches thick will be constructed around the well protective casing.

To protect above-ground completions in traffic areas, 3-inch diameter steel posts may be installed radially from the well casing at a distance of approximately 4 feet. They will be placed approximately 2 feet below the ground surface and have a minimum of 3 feet above the ground surface. The posts may be flagged in areas of high vegetation.

### **2.4.5 Measurements**

Measurements collected during drilling and well construction, including the well construction materials, will be measured to the nearest 0.1 foot. Following well completion, the well location will be surveyed by a licensed surveyor. The horizontal location will be measured to 0.1 foot and will be tied to the local, documentable coordinates. A survey reference mark for the vertical elevation will be placed on top of the well casing, for use as a measuring point. The height of the top of the well casing and the ground surface should be determined within  $\pm 0.01$  feet relative to mean sea level.

## **2.5 Documentation and Records Management**

General field documentation procedures are described in SOP entitled Field Documentation. Observations and data acquired in the field during drilling and

installation of wells will be recorded daily by the onsite geologist or engineer to provide a permanent record of these activities. These observations will be recorded with waterproof ink in a field book. The recorded information will include the following as a minimum:

- ☐ Project name and number;
- ☐ Observer's name;
- ☐ Drilling company name;
- ☐ Type of drill rig;
- ☐ Date drilling started and finished;
- ☐ Type of bit and size;
- ☐ Casing sizes and depths;
- ☐ Driller's name;
- ☐ Drilling and well installation observations;
- ☐ Presence and/or frequency of fractures and any lost circulation zones (to aid in identifying zones of potential hydrostatic head problems associated with placement of the grout seal);
- ☐ Daily progress;
- ☐ Geophysical log runs, calibration performed, and measurements collected;
- ☐ Problems encountered and resolution;
- ☐ Decontamination observations; and
- ☐ Weather conditions.

At the end of each day the onsite geologist or engineer will complete the field book notes and make two copies, if practicable: one for the task management files and one for the field files. In addition, daily drilling summary forms will be provided by the drilling contractor and will be approved by the onsite geologist or engineer. A copy will be included in the task management and field files.

A well construction summary form will be completed for each monitoring well or piezometer. Each well report form will include the following (denoted by depth from ground surface):

- ☐ Bottom of the borehole;
- ☐ Casing types and sizes;

- ☐ Screen (perforation) type and interval;
- ☐ Coupling/joint locations ;
- ☐ Filter pack type, size, and interval;
- ☐ Bentonite seal interval;
- ☐ Cave-in locations;
- ☐ Centralizer types and locations;
- ☐ Height of riser without cap (above ground surface); and
- ☐ Protective surface casing detail.

Additional documentation for well construction that will be recorded daily in the field book and/or appropriate forms will include the following:

- ☐ Sand, and bentonite volume calculations prior to well installation;
- ☐ The quantity and composition of the seals and filter pack actually used during construction;
- ☐ Screen slot size (in inches), slot configuration, total open area per foot of screen, outside diameter, nominal inside diameter, schedule and/or thickness and composition;
- ☐ Coupling/joint design and composition;
- ☐ Centralizer design and composition;
- ☐ Surface casing composition and nominal inside diameter;
- ☐ Start and completion date;
- ☐ Discussion of all procedures and any problems encountered during drilling and well construction; and
- ☐ Surface completion information and date.

### **3.0 QUALITY ASSURANCE**

Field notes and field forms completed by the field geologist shall be reviewed by the field supervisor and the Project Manager or other designated QA officer before they are placed into project files. Deviations from this SOP or a project-specific work plan shall be identified and described in field notes. The QA review will be recorded on the reviewed originals by initials of reviewer and date.

## **SOP No. 20 Data Review and Validation**

## **STANDARD OPERATING PROCEDURE No. 20**

### **DATA REVIEW AND VALIDATION**

#### **1.0 SCOPE AND APPLICABILITY**

This Standard Operating Procedure (SOP) describes the procedures for the evaluation of data generated through inorganic laboratory analysis of samples. These procedures apply to three levels of data evaluation: data completeness check, data review and data validation.

The QAPP, Sampling and Analysis Plan (SAP) and/or any other relevant site-specific or project-specific documents must be reviewed before this SOP is used to evaluate data. The individual performing the data evaluation shall be familiar with the analytical methods and other procedures used for the project. Familiarity with project and laboratory quality control requirements is critical to appropriate use of this procedure. A general description of the different levels of data evaluation is provided below and discussed in detail in Section 4.0 of this SOP.

##### **1.1 Data Completeness Check**

Data completeness checks may be performed on both Level 2 standard data reports and Level 4 USEPA Contract Laboratory Program (CLP)-like laboratory reports as specified in the project planning documents and/or by the project team or regulatory agencies.

These completeness checks may be performed as part of a data review or validation or may be performed as a stand-alone evaluation. Completeness checks only document the presence or absence of applicable QC data in the laboratory data package, and no qualification of sample results is necessary based on this data evaluation.

##### **1.2 Data Review**

Data review includes a review of laboratory quality assurance (QA) and quality control (QC) sample results provided in Level 2, or equivalent, standard laboratory reports. Data review can also be performed on CLP-like Level 4 data packages if required. In addition to sample results, Level 2 laboratory reports provide QA/QC summaries that

typically include results for method blanks, laboratory control samples (LCS), matrix spike (MS) samples, and duplicates, as well as the review of field QC samples (e.g., field blanks and field duplicates). Data review is differentiated from data validation because the review consists of an assessment of the laboratory QA/QC summary reports only.

### 1.3 Data Validation

Data validation includes the evaluation of the QA/QC results described above as well as an evaluation of additional validation of calculations, calibrations, internal standards, tunes, etc. provided in Level 4 CLP-like data reports. A minimum of 10% of the data reports produced annually by each laboratory analyzing environmental monitoring samples will be reported as CLP-like data reports and validated according to the data validation procedures described in this SOP (Section 4.3). Data validation of the CLP-like data reports will be performed using the general protocols and processes described in this SOP, as applicable to the method calibration and QC limits specified on Tables 2-2 through 2-6 of the QAPP, the Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Data Review (NFG; USEPA, 2010) and to the extent possible when certain non-CLP methods are used, laboratory SOPs.

The following table summarizes the common elements and differences between a data completeness check, data review and data validation.

**Scope of Data Reviews**

Item	Data Completeness Check	Data Review	Data Validation
Review of Work Plan, SAP and/or QAPP	Presence only	X	X
Review of Chain-of-Custody Records	Presence only	X	X
Review of Case Narrative	Presence only	X	X
Verify that preservation and holding time requirements met.	Presence only	X	X
Verify that the required frequency of field QC samples was met.	Presence only	X	X
Verify that ICP/MS tune analyses were performed at the required frequency and that results are within control limits.			X

Verify that all instrument calibration were performed at the required frequency and concentrations and that results are within control limits.			X
Verify that laboratory blanks were performed at the required frequency and that results are within the control limits.	Presence only	X	X
Verify that field blank results are within the control limits.	Presence only	X	X
Verify that all Laboratory Control Sample (LCS) were performed at the required frequency and that results are within control limits.	Presence only	X	X
Verify that matrix spike (MS) sample were performed at the required frequency and that results are within control limits.	Presence only	X	X
Verify that analytical duplicates were performed at the required frequency and that RPDs are within control limits.	Presence only	X	X
Verify that ICP Serial Dilutions were performed at the required frequency and that results are within control limits.			X
Verify that ICP/MS internal standards were included with each sample and that results are within control limits.			X
Verify that field duplicate measurements are within the control limits.	Presence only	X	X
Verify sample calculations.			X
Verify that project completeness goals were met.		X	X

## 2.0 BASIS FOR METHODOLOGY

The data evaluation procedures described in this SOP are based on the guidance specified in the QAPP and the protocols specified in the USEPA Contract Laboratory Program (CLP) National Functional Guidelines (NFGs) for Inorganic Superfund Data Review (USEPA, 2010). The data evaluation procedure described in this SOP may be used for the evaluation of standard laboratory data reports (Level 2 reports) or CLP-like/Level 4 laboratory data reports. CLP-like/Level 4 data reports are needed in order to complete the validation procedure described in this SOP. It is not meant to replace or incorporate all of the procedures and protocols necessary to complete data validation

per the USEPA NFGs. Data qualification may or may not be performed for data review, however data validation will include data qualification.

### 3.0 DEFINITIONS

Definitions of accuracy, precision, and completeness and methods for computing their measures are provided below. Descriptions of the contents of Level 2 Standard data packages and Level 4 CLP-like data packages are provided in Section 4.2 of this SOP.

#### a. Accuracy

Accuracy is the degree of difference between the measured or calculated value and the true value. Data accuracy and analytical bias are often evaluated by the analysis of LCS and MS samples, with results expressed as a percentage recovery measured relative to the true (known) concentration.

The percentage recovery for LCS samples is given by:

$$\text{Recovery (\%)} = \frac{A}{T} \times 100$$

where: A = measured concentration of the surrogate or LCS; and  
T = known concentration.

The percentage recovery for MS samples is given by:

$$\text{Recovery (\%)} = \frac{A - B}{T} \times 100$$

where: A = measured concentration of the spiked sample;  
B = concentration of unspiked sample; and  
T = amount of spike added.

Laboratory blanks, and often, field blanks are analyzed to quantify artifacts introduced during sampling, transport, or analysis that may affect the accuracy of the data.

## b. Precision

Precision is the level of agreement between duplicate measurements of the same characteristic. Laboratory precision, or analytical error, is assessed by determining the agreement of results for replicate measurements of the same sample. Field precision is assessed by determining the agreement for results for two independent samples collected from the same site at the same time. Precision may be evaluated using LCS/LCSD samples, MS/MSD samples, analytical duplicate samples and/or field duplicate samples. The comparison is made by calculating the relative percent difference (RPD) as given by:

$$\text{RPD (\%)} = \left| \frac{2(S1 - S2)}{S1 + S2} \right| \times 100$$

where: S1 = measured sample concentration; and  
S2 = measured duplicate concentration.

## c. Completeness

Completeness is the percentage of usable data measurements obtained, as a proportion of the number of data measurements planned for the project. Completeness is affected by such factors as sample bottle breakage and acceptance/non-acceptance of analytical results. Percentage completeness (C) is given by:

$$C (\%) = \frac{V}{P} \times 100$$

where: V = number of usable data measurements obtained; and  
P = number of data measurements planned.

#### d. Data Qualifier Flags

As a result of the data review or validation procedures (but not data completeness checks), data qualifier flags may be applied to individual analytical results if qualification for project data usability is appropriate. Definitions of the flags applied for data qualification are as follows:

<u>Flag</u>	<u>Definition</u>
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
J+	The result is an estimated quantity, but the result may be biased high.
J-	The result is an estimated quantity, but the result may be biased low.
R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.
U	The analyte was analyzed for, but was not detected above the level of the reported sample quantitation limit.
UJ	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.

An explanation regarding the assignment of qualifiers in accordance with the review procedures is detailed below in Section 4.2.

## 4.0 PROCEDURES

The data evaluation documentation requirements and procedures for data completeness checks, data review, and data validation are described below in the following sections.

#### 4.1 Data Completeness Check Procedure

Data completeness checks can be performed as a stand-alone evaluation or as part of a full data review or validation. A data completeness check is performed to verify that the laboratory data provided are complete. The following shall be reviewed for Level 2 Standard data reports and Level 4 CLP-like data reports.

Level 2 Standard data reports shall include the following information for each sample:

- ☐ Field and laboratory sample identification;
- ☐ Sample result, method detection limit, and reporting limit, with appropriate units;
- ☐ Dilution factor
- ☐ Sample collection, receipt, and analysis dates;
- ☐ Analytical method(s) references; and
- ☐ Laboratory qualifiers and definitions.

In addition, Level 2 Standard data reports shall include the following information in a QA/QC summary:

- ☐ Method blank results for each analyte;
- ☐ LCS results and laboratory control limits for each analyte;
- ☐ MS results and laboratory control limits for each analyte, if applicable;
- ☐ Analytical duplicate results and laboratory control limits for each target analyte (LCSD and/or MSD results may be provided instead of analytical duplicate results); and
- ☐ Confirmation of instrument calibration; and
- ☐ Copies of the signed COCs.

Level 4 CLP-like laboratory reports shall include the following information for each sample, at a minimum:

- ☐ Field and laboratory sample identification;
- ☐ Sample result, method detection limit, and reporting limit, with appropriate units;
- ☐ Sample collection and receipt dates;
- ☐ Sample preparation and analysis date/time;
- ☐ Dilution factor;
- ☐ Preparation and analysis batch numbers or identification;

- ☐ Sample matrix;
- ☐ Analytical method(s) references;
- ☐ Percent moisture determination; and
- ☐ For solid-matrix samples, identify basis of reporting (i.e., wet-weight or dry-weight basis).

The following additional information will also be provided in Level 4 CLP-like data reports, as applicable for the reported analytical methods:

- ☐ Case narrative;
- ☐ Copies of the signed COCs;
- ☐ Laboratory method/preparation blank;
- ☐ Initial calibration verification (ICV), and continuing calibration verification (CCV);
- ☐ Initial calibration blanks (ICB), and continuing calibration blank (CCB);
- ☐ Interference check sample, if applicable;
- ☐ Matrix spike (MS), and when applicable matrix spike duplicate (MSD), sample recovery and, when applicable, MS/MSD relative percent difference (RPD);
- ☐ Post-digest spike sample recovery;
- ☐ Laboratory duplicate;
- ☐ Laboratory control sample (LCS) recovery;
- ☐ ICP and ICPMS serial dilution percent differences;
- ☐ MDLs;
- ☐ ICP inter-element correction factors;
- ☐ ICP and ICPMS linear ranges;
- ☐ Preparation log;
- ☐ Analysis run log;
- ☐ Instrument raw data for verification;
- ☐ ICPMS tunes;
- ☐ ICPMS internal standards relative intensity summary;
- ☐ Sample log-in sheet; and
- ☐ Deliverables inventory sheet.

## 4.2 Data Review Procedure

The data review procedure for review of a Level 2 Standard data report is as follows. Data may or may not be qualified during data review depending on the project specifications.

- A. Review copies of the Chain-of-Custody records (COCs). Verify that all necessary information was provided on each COC and that all necessary signatures are present. Review laboratory records of sample temperature upon receipt and preservation information, if available, to verify that samples were properly preserved. Professional judgment may be used to determine if data qualification is necessary due to temperature exceedances and/or preservation deviations. Verify that all samples listed on the COCs were analyzed for the appropriate parameters. Note any problems documented on the COCs by either the laboratory or the sampler.
- B. Briefly review and summarize the laboratory case narrative, if present. Note any data that are indicated as outside of control limits.
- C. For each sample and each parameter, verify that the analyses were performed within the recommended holding time. For sample analyses performed outside the recommended holding times, sample results may be qualified as described in the QAPP or USEPA NFGs (2010), though professional judgment and project-specified requirements should be used.
- D. Identify any field QC samples and verify that the field QC samples specified in the Work Plan, QAPP or other relevant project documents have been collected at the correct frequency.
- E. Review the results of all field/equipment blanks and the laboratory method blanks. If an analyte was detected in a blank, the corresponding sample concentrations will be compared to the blank concentrations. Sample results may be qualified as described in the QAPP or USEPA NFGs (2010), though

professional judgment should be used to carefully evaluate the effect of blank concentrations on the sample data.

- F. Check the matrices, units, detection limits and reporting limits to verify that they are reported correctly and meet the project-specific requirements, if provided.
- G. Review all LCS (and LCSD, if available) recoveries and verify that they were within the project-specified control limits. If project-specific control limits are not provided, use the laboratory's control limits. LCS materials may not be available for all matrices. Sample results may be qualified as described in the QAPP or USEPA NFGs (2010), though professional judgment and project-specified requirements should be used.
- H. Review all MS (and MSD, if available) recoveries and verify that they were within the project-specified control limits. If project-specific control limits are not provided, use the laboratory's control limits. If analyzed and reported, post-digestion spike information should also be reviewed. Sample results may be qualified as described in the QAPP or USEPA NFGs (2010), though professional judgment and project-specified requirements should be used. For MS results that do not meet the control limits, the reviewer may choose to apply qualifiers to all samples of the same matrix associated with the MS, if the reviewer considers the samples sufficiently similar.

If an analytical duplicate was analyzed, compare the laboratory calculated RPD and compare this to the project-specified control limits. If a project-specific control limit is not available, use the laboratory's control limits. However, if one or both of the results are less than five times the PQL, use  $\frac{1}{2}$  PQL as the control limit for aqueous samples and  $2 \times \frac{1}{2}$  PQL as the control limit for non-aqueous (i.e., soil, sediment, tissue) sample matrices unless project-specific control limits are provided. If the analytical duplicate results fall outside of the control limits, sample results may be qualified as described in the QAPP or USEPA NFGs (2010), though professional judgment and

project-specified requirements should be used, LCS/LCSDs and/or MS/MSDs may be analyzed in place of, or in addition to, an analytical duplicate. The RPDs for LCS/LCSD and MS/MSD pairs shall be evaluated in the same manner as described above for analytical duplicates.

- I. If field duplicates were analyzed, calculate the RPD for each parameter and compare the RPDs to project-specified control limits. If project-specific control limits are not available, use 30 percent for aqueous samples and 50 percent for soil/solid/vegetation tissue samples. However, if one or both of the results are less than five times the PQL, use  $\frac{1}{5}$  PQL as the control limit for aqueous samples and  $2 \times \frac{1}{5}$  PQL as the control limit for non-aqueous (i.e., soil, sediment, tissue) sample matrices unless project-specific control limits are provided. If the field duplicate results fall outside of the control limits, the associated field duplicate results should be qualified in the same manner described above for analytical duplicates as described in the QAPP or USEPA NFGs (2010), though professional judgment and project-specified requirements should be used. Professional judgment will be used to determine whether additional sample results, in addition to the field duplicate sample results, should also be qualified.
- J. Determine whether the project's analytical completeness goal was met. Note any rejected data.

The data reviewer may also provide a brief summary of the accuracy, precision and completeness of the data set. The qualifier flags assigned to the data will be summarized in a table and/or entered into the electronic data deliverable, as specified in the project's QAPP or SAP.

#### **4.3 Data Validation Procedure**

A minimum of 10% of the data reports produced annually by each laboratory analyzing environmental monitoring samples from Smoky Canyon Mine will be reported as CLP-like data reports and validated according to the data validation procedures described in this SOP. The data validation procedure shall include all of the above steps in the data

review procedure with additional steps as outlined below. These additional steps include the recalculation of instrument and sample results from the laboratory instrument responses for a subset of the data. These recalculated results are compared to the laboratory reported results to confirm that the instrument outputs were correctly reported. Also, additional QC summary reports will be reviewed including the ICP/MS tune summary, the instrument calibrations, the interference check sample summary, the serial dilution sample summary, and the internal standard relative intensity summary. Data will be qualified during the data validation procedure with the appropriate qualifiers as specified in the QAPP and consistent with USEPA's NFG (2010). A more complete description of the additional steps to be followed in data validation is presented below.

- A. Verify sample calculations for a few of each sample results and identify and document any calculation errors if any are present. The raw instrument output will be reviewed to confirm that the analyte concentrations were reported correctly.
- B. Verify that the ICP/MS tune analysis data requirements were met and results were within QC limits. Review the raw data for a subset of the tune results and confirm that the raw data matches the results summarized on the ICP-MS Tune summary form. If the ICP/MS tune analysis results fall outside of the control limits, the associated sample results should be qualified as described in the QAPP or USEPA NFGs (2010).
- C. Verify that the instrument calibration was performed at the required frequency, that results are within QC limits, and review associated standards, including initial and continuing calibration standards and blanks. For a subset of the analytes, recalculate the percent recoveries for calibration standards using the data on the Initial and continuing calibration verification summary form and verify that the concentrations reported on this form are consistent with those in the instrument output. For ICVs/CCVs that have percent recoveries outside of control limits and for calibration blanks for which analytes are detected, review the run logs to confirm which samples were affected by out of control CCVs and CCBs. Associated sample results should be qualified as described in the QAPP or USEPA NFGs (2010) though professional judgment and project-specified requirements should be used.

- D. Verify that Interference Check Sample data requirements were met and results are within QC limits. Recalculate a subset of the percent recoveries and review the raw data to verify that the results from the instrument output match those reported on the Interference Check Sample summary form. If the interference check sample results fall outside of the control limits, the associated sample results should be qualified as described in the QAPP or USEPA NFGs (2010).
- E. Verify that ICP serial dilutions requirements were met and results are within QC limits. Recalculate percent differences for a subset of the results and verify that instrument outputs match values reported in the summary form. Where percent differences exceed the control limit and sample results are greater than 50 times the method detection limit, the associated sample results should be qualified as described in the QAPP or USEPA NFGs (2010).
- F. Verify that ICP/MS internal standard requirements were met and results within QC limits. Review raw data and recalculate a subset of the relative intensities of the internal standards and compare them to those reported on the internal standard relative intensity summary form. The associated sample results should be qualified as described in the QAPP or USEPA NFGs (2010).

Qualify all sample data associated with QC or calibration that do not meet the project specifications or QC limit using the appropriate qualifiers as defined in Section 3.4 Data Qualifiers. Use the guidance for data qualification from the project specific guidelines in the QAPP or guidance in the USEPA NFG (2010).

## 5.0 DOCUMENTATION

The data evaluation procedures and results will be documented through completion of a checklist, worksheet or summary document, subject to review and approval by the appropriate project representative(s). The data evaluation documents will be provided to the Project Manager and included in the project file containing the associated laboratory result reports.

Include the project name, project number, laboratory name, laboratory project number, field sample IDs, sample matrix, and analytical parameters and methods used on the data evaluation documentation forms. Specify the relevant project-planning documents and reference the protocol that was used to perform the data evaluation (such as this SOP).

A data review checklist is provided in Attachment A and a data validation checklist is provided in Attachment B. The table in Section 1.3 or list of report contents in Section 4.1 can be used as the basis for a checklist of the data completeness check.

## 6.0 DATA USE

Qualifier flags are assigned to describe the degree to which individual values provide accurate and precise results. The general criteria for assigning flags and their meaning in terms of future data use are as follows:

- ☐ Values assigned J flags (J, J+, or J-) are considered estimated results. QC data supplied with those values indicate that they may not be accurate or precise within the limits specified in the QAPP or a project-specific document, but that the magnitude of the potential imprecision or inaccuracy is not great enough to reject the value for project data uses.
- ☐ Values assigned R flags do not meet the requirements for accuracy, precision, representativeness, or reproducibility specified to provide quantitative data for the project data uses. The R flag indicates that serious deficiencies were encountered preventing the generation of usable data for the project objectives.
- ☐ Values assigned U flags indicate that a concentration of the analyte cannot be confirmed due to the presence of an interferant or the presence of the analyte in associated blanks. UJ flags may be applied to indicate that the presence of the analyte cannot be confirmed and the value of the reported quantitation limit for the sample may not be accurate or precise. Values flagged with U or UJ are fully usable and should be considered undetected.
- ☐ Values without flags assigned have met all of the project data quality objectives and are suitable for all project data uses.

## 7.0 QUALITY ASSURANCE/QUALITY CONTROL

The data evaluation documents will be reviewed internally for conformance to the procedures described herein. Once any questions or comments resulting from that

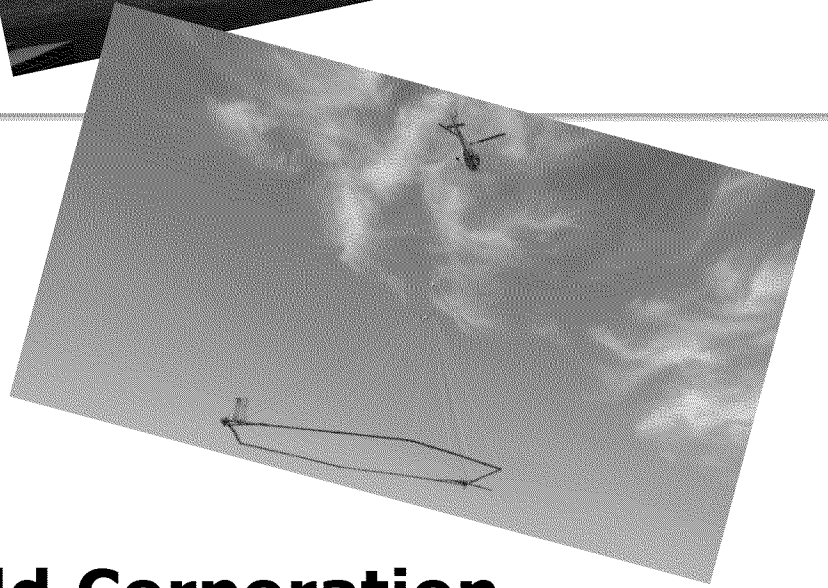
review have been resolved, the data evaluation documents will be considered final and any data qualifiers will be assigned to the results that are ultimately included in the project's electronic database.

## 8.0 REFERENCES

U.S. Environmental Protection Agency (USEPA), 2010. USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Data Review. EPA 540-R-10-011. January.

**Appendix C – HASP**  
**(To Be Provided at a Later Date)**

## **Appendix D – Geophysical Work Plan**



# Sunnyside Gold Corporation

**Collection of Airborne Electromagnetic  
and Total Field Magnetic data for the  
development of a 3D Framework over  
the Mayflower Tailings Silverton, CO**

Native Helicopters American Helicopters LLC

4300 Rogers Avenue Suite 200 #100  
Ft. Smith, Arkansas 72903  
(918)-720-6802

[nahelicopters@gmail.com](mailto:nahelicopters@gmail.com)



## 1. Introduction

Native American Helicopters, LLC ("NAH") is pleased to submit this proposal to the Sunnyside Gold Corporation- *Collection of Airborne Electromagnetic (AEM) and Total Field Magnetic data for the development of a 3D Framework over the Mayflower Tailings Silverton, CO*. Studies conducted by the U.S. Geological Survey (USGS) (Church and others, 2007) have indicated the presence of geophysically mappable features related to the hydrology and geology of the area. These hydrogeological features will be key in assessing the impacts and any potential remediation of the area.

The current study is designed to examine the following features:

1. Variations in the paleofluvial structure of the Animas River.
2. Understand the distribution of conductive fluids and their relationship to the tailings.
3. Lithologic character of the valley fill; and
4. The distribution of the tailings within the valley.

The previous USGS work utilized an early design of AEM systems that functioned in the frequency domain. The system was plagued with drift and bias that need extensive corrections before numerical inversion could occur (Church and others, 2007). The time-domain AEM system is better suited at imaging through conductive materials and imaging deeper than the frequency-domain system. Traditionally, the time-domain systems could not image the near surface due to frequency and bandwidth limitations. With the development of the short turn-off SkyTEM 301 (3  $\mu$ sec) system, near-surface layers can now be resolved and will still maintain an investigation depth  $\sim$  120 meters.

It is our understanding that:

- ∞ The Sunnyside Gold Corporation will provide a Contract Representative to assist in the QA/QC and logistical coordination

Please see Section 2 for a more thorough description of the duties and responsibilities of each company.

NAH utilizes the SkyTEM technology for data acquisition. SkyTEM technology benefits to the mapping objectives:

- ∞ As the only system capable of operating in dual transmitter modes, SkyTEM can discriminate between weak geological contrasts in the upper layers concurrently with those at depth.

- Low moment (LM) mode with low current, high base frequency and fast turn-off provides early -time data and high spatial sampling for shallow imaging.
- High moment (HM) mode with high current and low base frequency provides high quality late-time data for deep imaging.

The ability to map in dual mode makes it possible to map at depth as well as the near surface. It also will assist in discriminating more resistive layers.

- ∞ The extremely high signal to noise ratio contributes significantly to the delivery of high resolution data and increases confidence in determining overburden thickness and modeling of the deeper geology.
- ∞ Patented receiver technology eliminates signal drift and, combined with a one-time calibration procedure, data leveling and post flight corrections are minimized or eliminated. This also eliminates the need to conduct high altitude calibration/verification flights at regular intervals during each sortie. In addition to saving valuable survey time, this is of particular benefit when low ceiling or inclement weather could restrict survey productivity. As a result, preliminary data and simple inversion can be produced shortly after acquisition throughout the survey.
- ∞ Fast turn-off time and early time data. Early time data are important for resolving near surface layers as well as more resistive layers. SkyTEM's transmitter current is turned off within 3  $\mu$ sec and the first usable time gate opens at about 5  $\mu$ sec after the end of turn off). This allows for the collection of very clean and very accurate near surface data.
- ∞ All sensors, including the magnetometer, are mounted on the rigid carrier frame and flown at low altitude, ensuring that all measurements are recorded as close to the ground as is achievable from an airborne geophysical platform. This allows for increased accuracy and the collection of the highest lateral and horizontal resolution obtainable.
- ∞ The attitude of the SkyTEM system is measured directly with two inclinometers. Altitude is measured directly with the laser altimeters.
- ∞ No operator is required in the helicopter. This reduces weight and fuel consumption and serves to reduce risk and cost as the pilot is the only person aboard the aircraft during survey flying.
- ∞ The system is durable and can fly in challenging weather conditions.

The SkyTEM 301 system has been used to complete several engineering projects within North America for clients in the engineering, environmental, and resource exploration sectors. NAH utilizes an experienced staff of geophysicists, geologists, remote sensing specialists, and field survey operators to conduct airborne surveys. We support our clients and employees with a commitment to high standards in safety, quality and client service.

NAH will be partnering with Exploration Resources International (XRI) for technical expertise in the operation and use of AEM technology for hydrogeological mapping and construction of 3D hydrogeological frameworks. XRI specializes in geophysics and

hydrogeology, with a focus of expertise on aquifer mapping and hydrogeologic framework development in a variety of terrains. The information we develop from XRI's surveys is directly used for water resources management. Often, XRI's scientific productions are used for improving the understanding groundwater and surface water interactions, establishing groundwater management plans, managed aquifer recharge planning, municipal water supply development, and understanding groundwater quality.

XRI's staff of experienced scientists develop and apply techniques to supply subsurface information from geophysical surveys and traditional hydrogeologic methods. Our projects often lead to new developments in the field of hydrogeophysics, much of which is presented in scientific publications.

### **1.1. Validity**

This proposal is valid until July 31, 2015 and needs to occur immediately following the planned work in CA that NAH is engaged in, with an estimated completion date of July 20, 2015.

### **1.2. Contacts**

The primary contact person from NAH for this proposal will be:

B.J. Crocker  
Chief Executive Officer  
Native American Helicopters  
nahelicopters@gmail.com  
4300 Rogers Ave STE 20 #100  
Ft Smith, AR 72903  
(918)-720-6802 (c)

The primary Technical Contact will be:

Jared D. Abraham  
Senior Research Geophysicist  
XRI Geophysics, LLC  
14828 Unit 3B, W 6th Ave  
Golden, CO 80401  
(303)-263-8318 (c)

The primary contact person from Sunnyside Gold Corporation for this proposal will be:

Pat Maley  
Director, Environment  
Sunnyside Gold Corporation  
5075 South Syracuse Street, Suite 800  
Denver, CO 80237  
(303)-802-1449 (o)  
(775)-240-1288 (c)

### **1.3 Cited Publications**

Church, S.E., von Guerard, Paul, and Finger, S.E., eds., 2007, Integrated investigations of environmental effects of historical mining in the Animas River watershed, San Juan County, Colorado: U.S. Geological Survey Professional Paper 1651, 1,096 p. plus CD-ROM. [In two volumes.]

## **2. Services, Pricing, Payments and Insurance**

Note: Notwithstanding the delegation of the responsibilities of the Services noted below, it is anticipated that either party will provide suggestions, provide guidance and generally assist the other when it is deemed to be in the best interest of a successful project and/or is required by law.

### **2.1. Services to be provided by NAH:**

1. Preparation of flight line maps.
2. Supply all personnel.
3. All accommodations and meals for all crew.
4. Supply of all technical equipment and spares.
5. Supply of helicopter, fuel truck, and all required fuel.
6. Processing, quality control, and delivery of preliminary products on a daily basis.
7. Inversion of the AEM data for development of the 3D framework of the survey area.
8. Provide interpretations of the AEM inversions that integrate all available and useable data.
9. Production of final deliverables.

### **2.2. Services to be provided by Sunnyside Gold Corporation:**

1. Provide applicable data on the characteristics of the tailings and hydrogeological conditions of the area to be integrated into the 3D hydrogeological framework
2. Provide a Contract Representative to QA/QC the data and to provide logistical coordination with the Sunnyside Gold Corporation.
3. Warrant that it has the right to collect geophysical data over the survey area.
4. Obtain all necessary permits and approvals of any stakeholders required, including but not limited to local authorities.
5. Assist with notification of all local residents in the survey area.
6. Assist with logistical issues related to the survey area.

Pricing Page Redacted.

### 3. Survey Areas

#### 3.1. Outline of the survey areas

The survey will be conducted within the area of Silverton, CO figure 1.

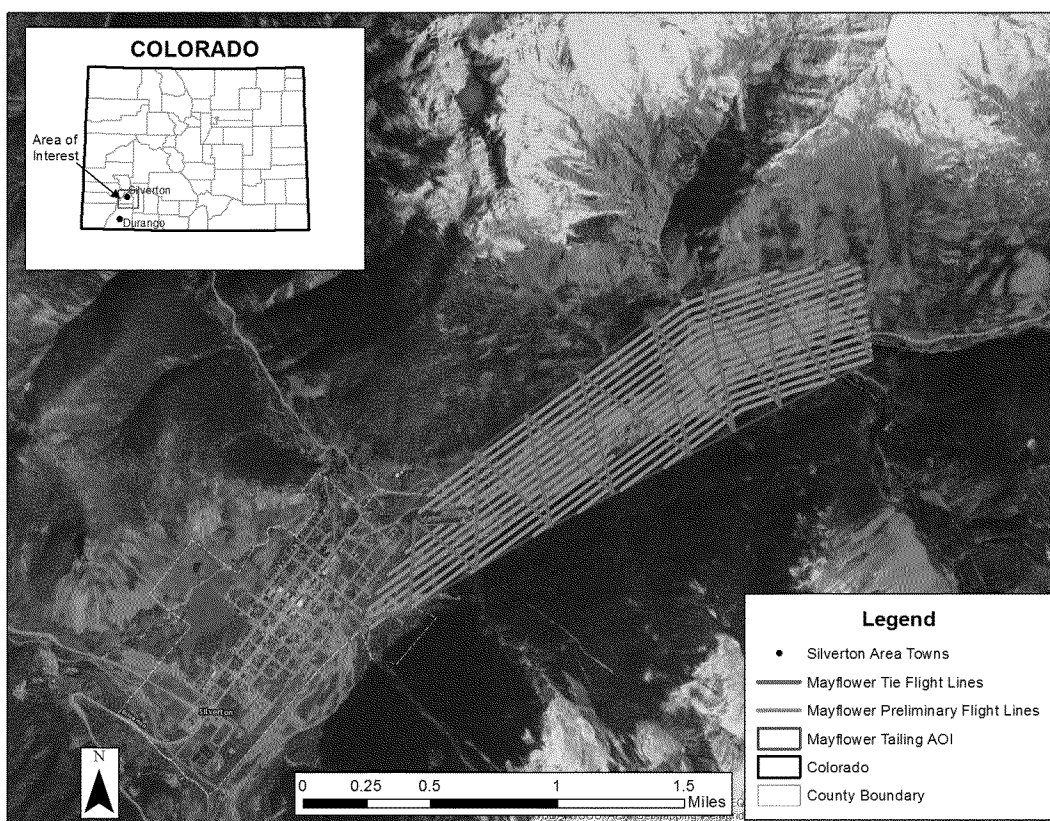


Figure 1: Location of the survey area near Silverton, CO.

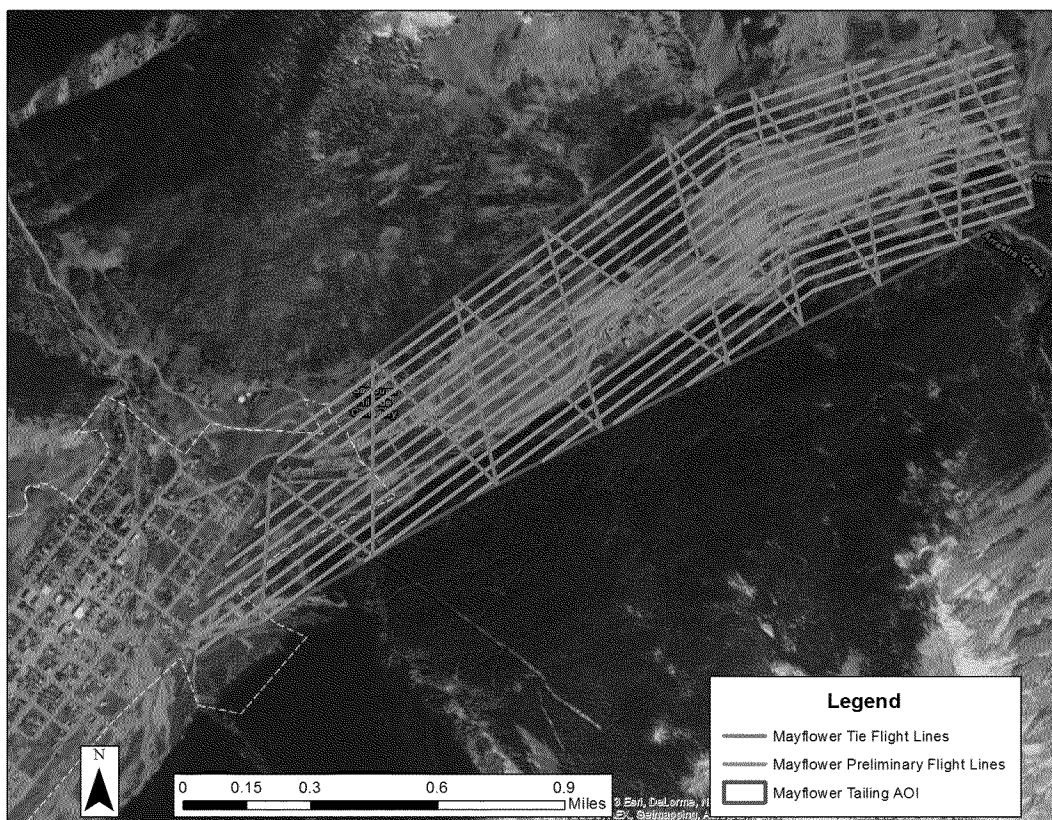


Figure 2: Approximate flight lines for the Mayflower Tailings Survey.

#### 4. Survey Scheduling

Mobilization to Silverton will begin at the completion of NAH work in California and is anticipated to be approximately on July 20<sup>th</sup>, 2015. Sunnyside Gold Corporation will have 5 days notice of the beginning of the survey date. This is based on the assumption that the contract award and negotiations are concluded in a timely fashion and weather or factors beyond NAH's control do not significantly affect the start date and survey operations. NAH will deliver the final report and products within 6 weeks of completion of the collection of data.

Preliminary products may be prepared progressively in the field during survey flying.

All phases of the survey schedule will be coordinated with the Sunnyside Gold Corporation.

Mobilization date	Late July 2015
Est. daily production	~50 line kilometers
Est. no of survey days	~1
Est. last day of flying	Will depend on weather conditions
Est. delivery date finals	Preliminary reports can be delivered progressively in the field. Finals 6 weeks from collection of data.

## Project workflow

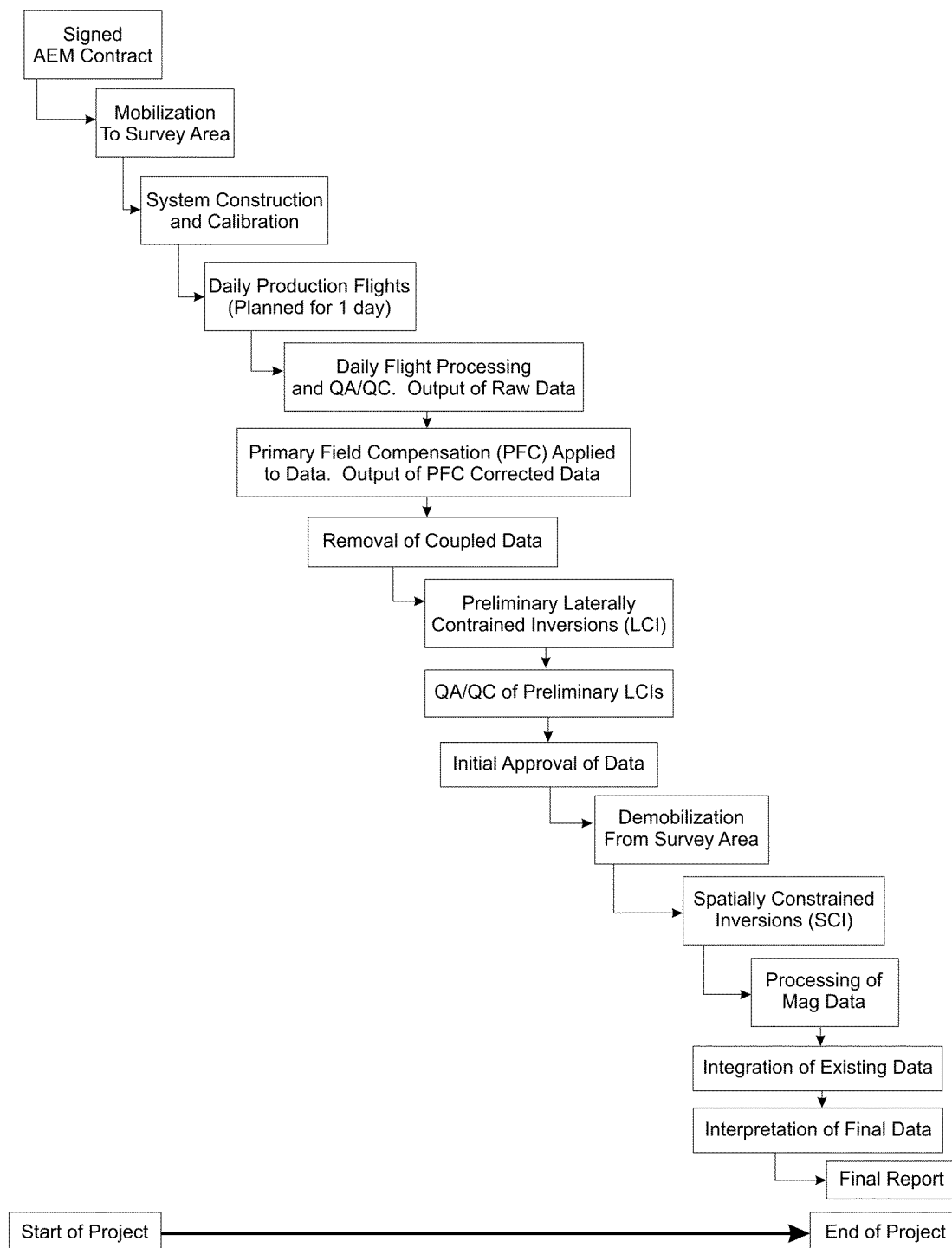


Figure 3: Project workflow.

## 5. Flight Specifications

Flight line specifications are outlined below (exclusions include any obstacle avoidance or other safety issue as judged by the pilot).

Maintain flight line X,Y tolerances to within  $\pm 10$  meters. Deviations from the flight line will not be  $> 10$  meters for a distance  $> 500$  meters.

Altitudes will be maintained at approximately 30 meters  $\pm 15$ m over the highest obstacle. Deviations from the planned altitudes will not be  $> \pm 15$  for a distance  $> 1,200$  meters.

With the difficult terrain of the Silverton area, the final survey layout will be more determined on the obstacle avoidance and terrain than specific flight lines.

## 6. Aircraft and Flight Specifications

Helicopter provider	NA Helicopters
Helicopter type	Astar 350FX2 Ecureuil (Squirrel)
Min/max operational temperature	-30°C to 45°C
Max cruise air speed without sling load	245 kph
Avg flight duration while survey flying	~2.5 hours
Avg production per flight	~120 line kilometers
Flights per day	2
Number of pilots	1
Co-pilot/operator	Not needed
Technician	1
Fuel	Fuel truck
Fuel consumption	~180 l/h

## 7. Specifications of the SkyTEM301 System and Auxiliary Equipment

### 7.1. General

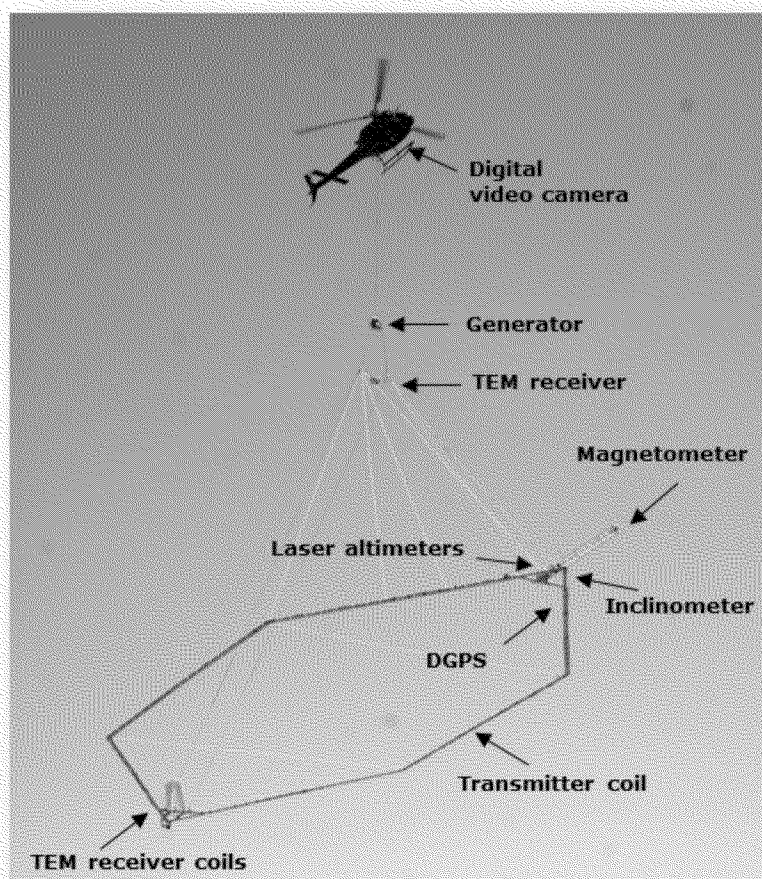


Figure 4: Photo of the AEM instrumentation mounted on the rigid carrier frame .

Total weight	500 kg
Length carrier frame	28 m (excluding the stinger for the magnetometer)
Width carrier frame	16.5 m
Length tow cable	35 m
Carrier frame	Rigid aerodynamic composite
Nominal terrain clearance	30 m above any obstacles or hazards <sup>*)</sup>
Production speed on survey lines	80-100 km/hr (optional fast flying up to 120 km/hr)
Max airspeed ferry	120 km/hr
Max wind speed	10 m/s – if gusty wind or demanding terrain conditions, the max wind will be reduced
Precipitation	Light precipitation can be tolerated
Operational temperature	-30°C to +45°C

<sup>\*)</sup> Dependent on terrain, weather conditions and pilot discretion. The EM carrier frame can be adjusted so that the helicopter speed can be reduced to suit terrain conditions and the pilot's ability to drape fly.

## 7.2. Transmitter

Electromagnetic system –Dual-Moment, Time-Domain Electromagnetic (TDEM) System.

Parameter	LM mode	HM mode
No of transmitter turns	1	1
Transmitter area per turn	341 m <sup>2</sup>	341 m <sup>2</sup>
Transmitter current	~6 Amp	~95 Amp <sup>*)</sup>
Transmitter dipole	Vertical	Vertical
Peak moment	~2,000 NIA	~32,000 NIA
On time	800 µs	2500 µs
Off time	715 µs	4167 ms <sup>**) </sup>
Rep. frequency	330 Hz	75 Hz
Power supply	External DC generator. Part of the sling load. Placed at an appropriate distance from the TDEM receiver and transmitter system to avoid any noise and data bias effects.	

<sup>\*)</sup> The current is dependent on the outdoor temperature. The current will be reduced as temperatures increase.

<sup>\*\*)</sup>  The system has customizable on times and repetition frequencies for both LM and HM modes. These parameters can be modified while the survey is taking place.

### 7.3. Waveform

The figures below show the normalized waveforms for the low and high moment transmitter modes measured on the ground. Only the positive waveform is shown as the positive and negative waveforms are fully symmetrical. Note the significant difference in time scale between the Ramp Up (ms) and Ramp Down ( $\mu$ s) figure panels.

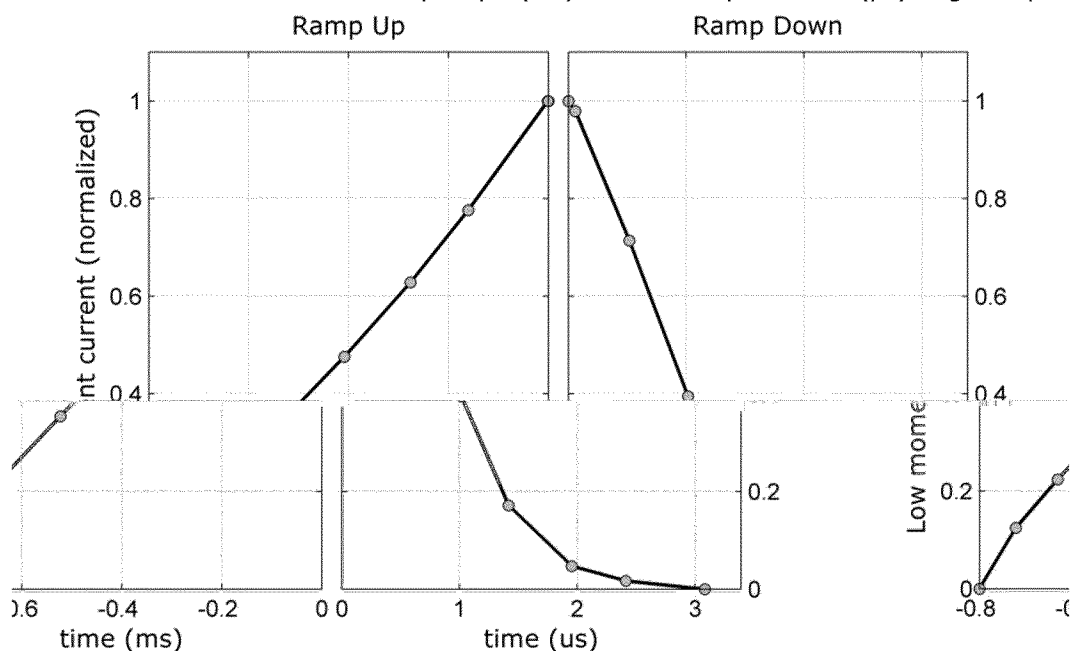


Figure 5: The digitized waveform for the low moment. Left axis is the normalized current (Ampere), bottom axis is time in ms for ramp-up and  $\mu$ s for ramp-down.

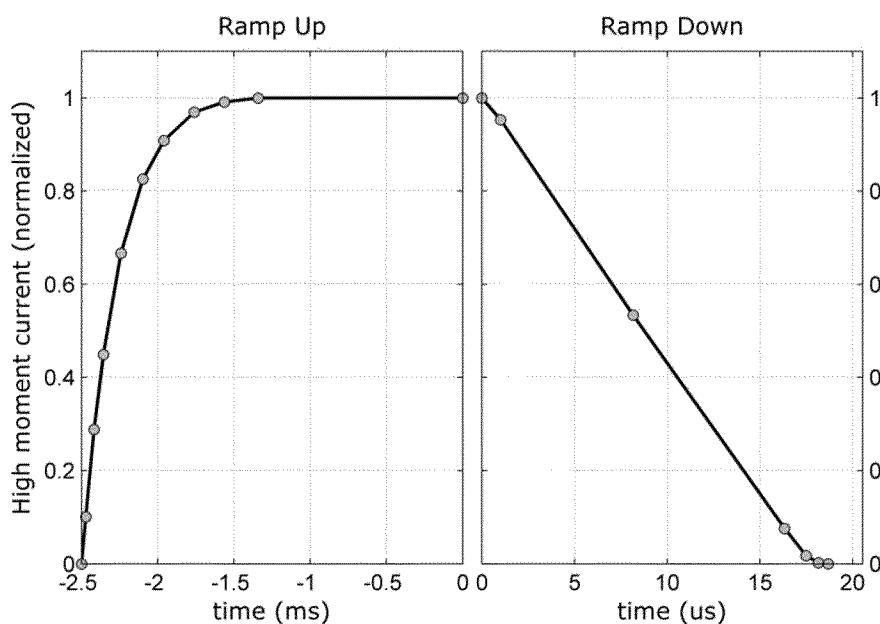


Figure 6: The digitized waveform for the high moment. Left axis is the normalized current (Ampere), bottom axis is time in ms for ramp up and  $\mu$ s for ramp down.

The full measured wave form will be supplied for both high and low moment in the final data delivery.

#### TDEM receiver

Receiver coils	Shielded, optimally damped, multi-turn air-cored loops, sensitive to dB/dt
Z coil frequency	650 kHz
X coil frequency	250 kHz
Effective area of Z coil	105 m <sup>2</sup>
Effective area of X coil	115 m <sup>2</sup>
Receiver bandwidth	500 kHz (customizable)
Operational temperature	-35°C to +50°C

#### TDEM gate times

The low moment and high moment signals are recorded using time gate averaging. The gate center times and gate averaging widths are shown in the tables below. The gate center times refer to the end of the current ramp down for both moments. The high moment current ramp down is essentially linear and has a duration of approximately 18  $\mu$ s. The shape of the low moment current ramp down is more complicated. We define its duration to be that of the equivalent linear ramp down having the same area. The equivalent linear ramp down has a duration of approximately 2  $\mu$ s.

Low Moment		
Window	Gate Center ( $\mu$ s)	Gate Width ( $\mu$ s)
1	4.2	1.6
2	6.2	1.6
3	8.2	1.6
4	10.2	1.6
5	12.7	2.6
6	16.2	3.6
7	20.7	4.6
8	26.2	5.6
9	33.2	7.6
10	42.2	9.6
11	53.7	12.6

Low Moment		
Window	Gate Center (μs)	Gate Width (μs)
12	68.2	15.6
13	86.2	19.6
14	108.7	24.6
15	136.7	30.6
16	172.2	39.6
17	217.7	50.6
18	274.7	62.6
19	346.7	80.6

High Moment		
Window	Gate Center (μs)	Gate Width (μs)
1	44.2	9.6
2	55.7	12.6
3	70.2	15.6
4	88.2	19.6
5	110.7	24.6
6	138.7	30.6
7	174.2	39.6
8	219.7	50.6
9	276.7	62.6
10	348.7	80.6
11	439.7	100.6
12	553.7	126.6
13	697.7	160.6
14	879.2	201.6
15	1107.7	254.6

High Moment		
Window	Gate Center (μs)	Gate Width (μs)
16	1396.2	321.6
17	1760.2	405.6
18	2218.7	510.6
19	2796.7	644.6
20	3525.7	812.6

The above gate time tables relate to the specific repetition rates shown in the transmitter section. Repetition rates and gate timings are fully customizable and can be readily adapted to specific customer requirements.

#### 7.4. Airborne magnetometer

Number	1
Type	Geometrics Caesium Vapour type 822A, Total intensity magnetometer
Sampling interval	Defined by the TDEM HM repetition frequency
Magnetometer values	Down sampled to 10 Hz data
Error envelope	Not exceeding $\pm 0.2$ nT for more than 10% of any flight line
Synchronization	With TDM system to measure in HM off times
Operating principle	Self-oscillating split-beam Caesium Vapour (non-radioactive)
Operating range	20,000 to 100,000 nT
Operating zones	The Earth's field vector should be at an angle greater than $6^\circ$ from the sensor's equator and greater than $6^\circ$ away from the sensor's long axis. Automatic hemisphere switching
Sensitivity	$< 0.0005$ nT/ $\sqrt{\text{Hz}}$ rms. Typically 0.002 nT P-P at a 0.1 second sample rate (90% of all readings falling within the P-P envelope) using 822A Super-counter
Heading error	$< 2$ nT

Absolute accuracy	Better than 3 nT throughout range	
Output	Cycle of Larmor frequency = 3.498572 Hz/nT	
Mechanical	Sensor	2.375" (60.32 mm) dia., 6.25" (158.75 mm) long, 12 oz (339 g) without cable
	Sensor electronics	2.5" (63.5 mm) dia., 11" (279.4 mm) long, 24 oz (680 g)
Operating temperature	-35°C to +50°C	
Altitude	Up to 9,000 m	
Counter	Kroum KMAG4	
Synchronization	The counter is synchronized with the TDEM system. The system only records magnetic data in the TDEM off time	
Power	24 to 32 VDC, 0.75 Amp at turn-on and 0.5 Amp thereafter	

## 7.5. Ground base magnetometer

Number	1 or 2	
Recording	Continuously	
Location	Within 100 km of all survey points	
Magnetic base station	One or two, of either type GEM GSM 19 Overhauser magnetometer and/or GEM GSM 19 Proton magnetometer with a sampling interval of 1 second and a sensitivity of better than 0.3 nT located so that sources of man-made noise such as vehicular traffic do not exceed 1 nT	
Digital recordings	Digital data include the date, an absolute value of the magnetometer and GPS time with accurate synchronization to the airborne data acquisition system	
<b>Specifications</b>	<b>Overhauser GSM-19W</b>	<b>Proton GSM-19TW</b>

Performance	<p>Sensitivity: 0.022 nT / <math>\sqrt{\text{Hz}}</math></p> <p>Resolution: 0.01 nT</p> <p>Absolute Accuracy: <math>\pm 0.1</math> nT</p> <p>Range: 20,000 to 120,000 nT</p> <p>Gradient Tolerance: &lt; 10,000 nT/m</p> <p>Samples at: 60+, 5, 3, 2, 1, 0.5, 0.2 sec</p> <p>Operating Temperature: -40°C to +50°C</p>	<p>Sensitivity: 0.15 nT @ 1 reading per sec.</p> <p>0.05 nT @ 1 reading every 4 sec.</p> <p>Resolution: 0.01 nT</p> <p>Absolute Accuracy: <math>\pm 0.2</math> nT @ 1 Hz</p> <p>Dynamic Range: 20,000 to 120,000 nT</p> <p>Gradient Tolerance: over 7000 nT/m</p> <p>Samples at: 60+, 5, 4, 3, 2, 1, 0.5 sec</p> <p>Operating Temperature: -40°C to +50°C</p>
Operating modes	<p>Manual: Coordinates, time, date and reading stored automatically at minimum 3-second interval.</p> <p>Base Station: Time, date and reading stored at 1- to 60-second intervals.</p> <p>Remote Control: Optional remote control using RS-232 interface.</p> <p>Input / Output: RS-232 or analog (optional) output using 6-pin weatherproof connector.</p>	<p>Manual: coordinates, time, date and reading stored automatically at minimum 3-second interval.</p> <p>Base Station: time, date and reading stored at 3- to 60-second intervals.</p> <p>Remote Control: optional remote control using RS-232 interface.</p> <p>Input / Output: RS-232 or analog (optional) output using 6-pin weatherproof connector.</p>
Dimensions	<p>Console: 223 x 69 x 240 mm</p> <p>Sensor: 175 x 75 mm diameter cylinder</p>	<p>Console: 223 x 69 x 240 mm</p> <p>Sensor: 170 x 71 mm diameter cylinder</p>
Weights	<p>Console with belt: 2.1 kg</p> <p>Sensor and staff assembly: 1.0 kg</p>	<p>Console: 2.1 kg</p> <p>Sensor and staff assembly: 2.2 kg</p>

## 7.6. Laser altimeter

The system is equipped with two devices for backup. Data is guaranteed to be supplied from one device and will in most cases be supplied from both devices. In the case that one device fails it will be replaced as fast as possible.

Number of units installed	2
Model	MDL ACE IM3R or IM3HR type 150 or 300

Wavelength	905 nm
Type	Digitized in the unit, filtered and time stamped in the unit
Reflector range	0.5 – 150 m or 2-300 m (passive reflector)
Time lag	Does not exist
Class	1 (comply with regulations with respect to the safe use of laser equipment)
Accuracy	20 cm
Resolution	10 cm
Rep. rate	Up to 1000 Hz
Output recording rate	Between 10-75 Hz
Position	One on each side of the carrier frame
Operating temperature	-20°C (some units modified to -30°C to +60°C)
Weight	260 g

## 7.7. Video camera

Video data is considered as additional data.

Number of units installed	1
Synchronization and stamping	Synchronized by use of GPS and stamped with time and position
Position	Downward looking, placed in the helicopter
Weight	267 g
Input voltage	9-15 V
Power	7.2 Watts maximum
Lap time accuracy	0.1 sec
Foot print in 65 m altitude	~120 m
Data storage	SD card
Data format	Interlaced MPEG 4 AVI files
Frames	25 or 30 fps
Graphics	24-bit color plus 16 levels of alpha transparency
Resolution	DVD 720 x 576 at 25 frames per second

	PAL (default) or DVD 720 x 480 at 30 frames per second NTSC
Operating temperature	-10°C to +60°C

## 7.8. DGPS – Rover

The system is equipped with two devices for backup. Data is guaranteed to be supplied from one device, and will in most cases be supplied from both devices. In the case that one device fails it will be replaced as fast as possible.

Number of units installed	2
Brand	Novatel
Model	OEMV-1, 14 GPS L1, 1 L-band, 2 SBAS
Antenna	Trimble Bullet III
Real time corrections	Real time SBAS
Coordinate system and datum	Lat_lon – WGS84 UTM – WGS84
Horizontal position accuracy	0.6 m (SBAS) 0.45 (DGPS post processing)
Data rate	20 Hz
Operating temperature	-40°C to +85°C

## 7.9. DGPS – base station

The system is equipped with two devices for backup. Data is guaranteed to be supplied from one device and will in most cases be supplied from both devices. In the case that one device fails it will be replaced as fast as possible.

Number of units installed	2
Brand	Novatel
Model	OEMV-1, 14 GPS L1, 1 L-band, 2 SBAS
Antenna	Trimble Bullet III
Real time corrections	Real time SBAS
Coordinate system and datum	Lat_lon – WGS84 UTM – WGS84
Horizontal position accuracy	0.6 m (SBAS)

	0.45 (DGPS post processing)
Data rate	1 Hz
Operating temperature	-40°C to +85°C

## 7.10. Inclination sensors

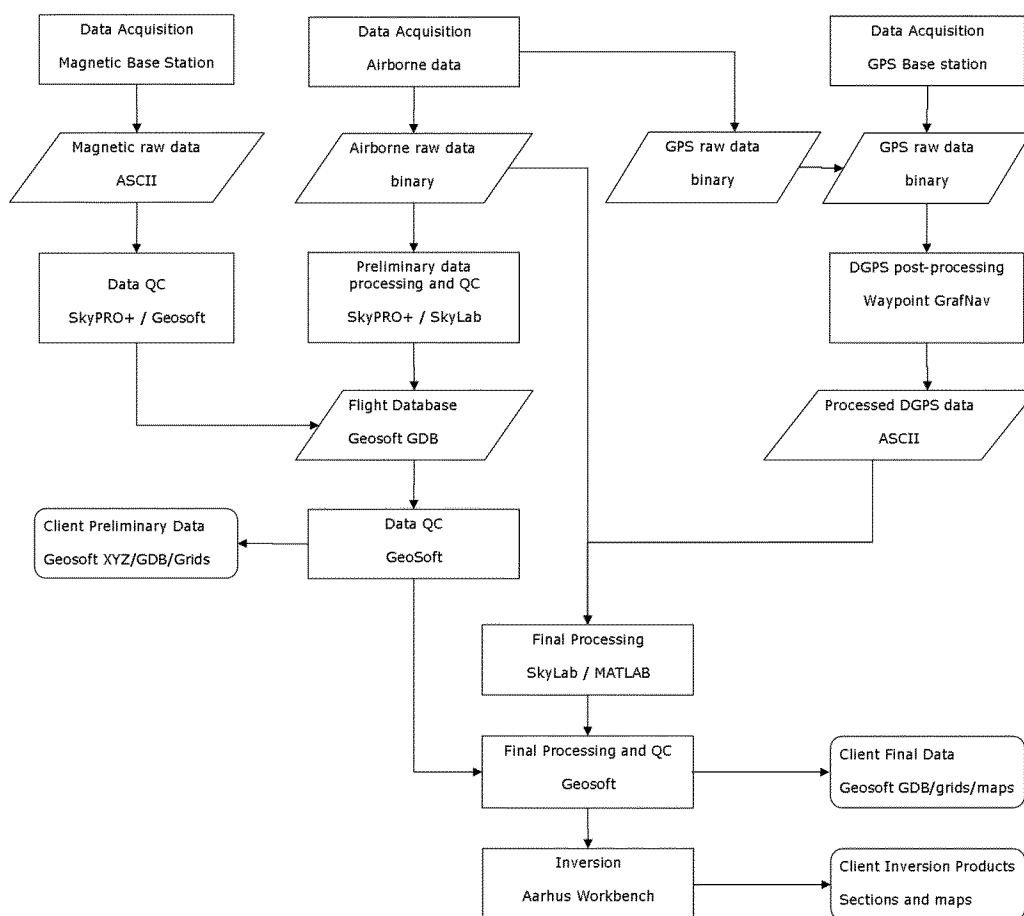
The system is equipped with two devices for backup. Data is guaranteed to be supplied from one device and will in most cases be supplied from both devices. In the case that one device fails it will be replaced as fast as possible.

Number of units installed	2
Model	Custom-designed Bjerre Technology inclination sensors to measure altitude of the carrier frame
Measurements	Data is transmitted digitally to the receiver electronics with no time lag
Orientation	Angle carrier frame in-flight direction (X) and perpendicular to the flight direction (Y)
Rep. rate	2 Hz
Resolution	0.1 degree
Accuracy	Better than 1 degree
Operating temperature	-20°C to +85°C

## Appendix A Data Processing and Deliverables

### A.1 Data workflow

The figure below shows the processing workflow for EM and magnetic data.



### EM data management, QA/QC and processing workflow

Final processing of the EM data is implemented in proprietary software and Geosoft's Oasis Montaj software for processing of airborne geophysical data.

The inversion of the TDEM data will be based on Aarhus Workbench, developed by Aarhus Geophysics and Aarhus University. The 1D interpretation technique provides the optimal view of the subsurface by its representation of layering (if layers are dipping 30 degrees or less). When using the robust and documented 1D inversion scheme, a valuable "by-product" is a determination of how well the resistivities are resolved and how well the model response fits the actual measured data.

1. Field processing:
  - a. The raw data are processed in proprietary software (SkyLab);
  - b. Raw preliminary EM data (not PFC corrected) in Workbench file format will be provided;
  - c. Daily data QC is performed in the office and field processing center.
  - d. Within 24 hours , preliminary EM data PFC corrected in Workbench file format will be provided; and
  - e. Within 36 hours, LCI-inversion in Aarhus Workbench are delivered.
2. Final processing:
  - a. Post processing of DGPS data;
  - b. Raw EM data are normalized with the effective area of Rx -coil and the transmitter moment;
  - c. Power line noise intensity (60Hz) is extracted; and
  - d. Filtered data are processed in GeoSoft and a final project master database (GeoSoft) comprising EM and magnetic data is produced.
3. SCI-inversion in the Aarhus Workbench:
  - a. The final processed and decoupled data are input into the Aarhus Workbench; and
  - b. Inverted resistivity models are plotted on resistivity sections and are delivered as Geosoft Databases.

### **Magnetic data management, QA/QC and processing workflow**

Final processing of the magnetic data involves the application of traditional corrections to compensate for diurnal variation, lag, heading effects , and levelling prior to gridding. Processes applied to improve the gridding include micro-levelling and application of higher order filter operators.

Advanced full processing of magnetic data is implemented in proprietary SkyLab software and Geosoft's Oasis Montaj software and its extensions for processing of Airborne Geophysical Data as follows:

1. Processing of static magnetic data acquired on magnetic base station-
  - a. Filtering;
  - b. IGRF correction ;
  - c. Calculation of diurnal variations; and
  - d. Calculation of QC parameters.
2. Processing of airborne magnetic data-
  - a. Filtering;
  - b. Standard corrections to compensate the diurnal variation, lag and heading effect;
  - c. IGRF correction;
  - d. Statistical leveling using control (tie) lines;
  - e. advanced leveling (care-full leveling and micro leveling)
  - f. Gridding;
  - g. Production of standard magnetic maps; and
  - h. Delivery of raw, corrected, and leveled data will provided

## **A.2 Preliminary field data**

Preliminary raw field data (not PFC corrected) in Workbench format (\*.skb) will be provided to the on-site representative at the end of each production day. Raw Field data

(PFC corrected) will be provided to the on-site representative within 24 hours, provided that sufficient internet reception is available to the NAH crew. The following preliminary LCI-inversion will be provided within 36 hours of acquisition to the Contract Representative-

- ∞ Raw electromagnetic data;
- ∞ Raw GPS data;
- ∞ Raw laser-altimeter data;
- ∞ Raw inclinometer data; and
- ∞ Related quality assurance and quality control documentation and records.

During the survey the recorded data will be carefully evaluated for QA/QC purposes and to ensure complete data coverage and high quality output. Geosoft as well as in-house software will be used to evaluate the data. This QA/QC procedure will be performed daily by the NAH crew.

### A.3 Final deliverables

This section describes the standard deliverables for data included in the survey.

#### Digital data

Digital data for each survey block will be delivered in Geosoft database (GDB) or XYZ format. Digital grids will be delivered in Geosoft grid format (GRD) or other standard grid format defined by XRI. Formats should be agreed before the survey begins. All final products will be delivered in digital format (FTP site).

#### EM and magnetic data

Data available for download in Geosoft with appropriate headers will include the processed flight line data. A header describing each of the channels and data will be included. In addition, all data that has been corrected and processed will be delivered in a format that can be input into Aarhus Workbench. Each record will contain the following fields for EM and magnetic data:

Channel Name	Description	Unit
Fid	Unique fiducial number. Fid with the value of 0.0 is equal to midnight on the date of YYYY/MM/DD	Seconds
Line	Line number	LLLLLL
Flight	Name of flight	yyyymmdd.ff
DateTime	DateTime format	Decimal days
Date	Date	yyyymmdd
Time	Time	HH:MM:SS.SSS
AngleX	Angle in flight direction	Degrees
AngleY	Angle perpendicular to flight direction	Degrees

Channel Name	Description	Unit
Height	Filtered height – terrain clearance	Meter
Lon	Longitude, WGS84	Decimal degrees
Lat	Latitude, WGS84	Decimal degrees
E	Easting, defined projection	Meter
N	Northing, defined projection	Meter
DEM	Digital Elevation Model	Meters above mean sea level
Alt	DGPS altitude	Meters above mean sea level
GdSpeed	Ground speed	[km/h]
Curr_1	Current, high moment	Amps
Curr_2	Current, low moment	Amps
LM_Z	Normalized LM Z-coil value in a Geosoft array channel	pV/(m4*A)
HM_Z	Normalized HM Z-coil value in a Geosoft array channel	pV/(m4*A)
LM_X	Normalized LM X-coil value in a Geosoft array channel	pV/(m4*A)
HM_X	Normalized LM X-coil value in a Geosoft array channel	pV/(m4*A)
PLNI	Power Line Noise Intensity	-
IGRF	Calculated IGRF- total magnetic intensity	nT
Inc	Calculated IGRF- magnetic inclination	Degrees
Dec	Calculated IGRF- magnetic declination	Degrees
Bmag	Raw TMI for ground magnetic base	nT
Diurnal	Diurnal variation– magnetic base station data	nT
Mag_raw	Raw magnetic data – total magnetic intensity – despiked	nT
Mag_fil	Filtered raw magnetic data - TMI	nT
Mag_cor	Residual magnetic field - corrected for diurnal, lag, heading, and IGRF	nT
RMF	Residual magnetic field – IGRF removed - final corrected and levelled magnetic data	nT
TMI	Total magnetic intensity – final corrected and levelled magnetic data; IGRF recalculated.	nT

## Digital maps

### Survey data

- ∞ Digital Elevation Model
- ∞ Flight path

### Interpretation and 3D Framework

The Aarhus Geophysics Workbench, specifically designed to process SkyTEM data, combined with XRI -developed software, will be used for the processing and inversion of the AEM data. The software is specifically suited for editing AEM data and removing couplings to power lines and pipelines. Spatially constrained inversions are conducted on the processed and decoupled data. Spatially constrained inversions utilize linear regularization from adjacent data points within the 1-D kernel function. Integration of borehole electrical data is typically done in areas where borehole data is coincident with the AEM data. The inversions are then combined into a 3-D electrical resistivity earth model of the area.

The AEM resistivity model combined with ground data will be used to reveal the character of the deposits across the project area with a level of three-dimensional detail that would be unobtainable with the limited ground access and the current inventory of borehole information. The interpretive imagery, which is inverted and derived from the AEM data, will illustrate contrasts between electrically conductive materials (clay and silt) and more electrically resistive sediments (sands and gravels) which correlate to the hydrological properties of clays and silts versus sands and gravels. The geologic descriptions from available borehole logs across the area are used as the base ground-truth. Interpretations are then provided as GIS and Google Earth files.

### Final report

A report describing the acquisition, processing, and interpretation of the geophysical data collected will be delivered within six weeks of the completed survey. The final report will be delivered in digital PDF format and will include:

- ∞ A description and diary of survey operations and processing;
- ∞ List of the personnel employed in the survey and processing;
- ∞ Details of the instrumentation employed;
- ∞ A summary of survey statistics and QC parameters;
- ∞ A summary of the results of checks and calibrations;
- ∞ A full description of data compilation and processing methods applied;
- ∞ A list of maps and other final products; and
- ∞ A full description of digital data formats.

### Other final deliverables

- ∞ Related quality assurance and quality control documentation and records.
- ∞ Flight path video showing the flight paths taken during the survey.

### **Digital data**

Raw data in SKB and SPS-file (SkyTEM's proprietary format) and geometry file for Workbench (Aarhus Geophysics software product).

## Appendix B Project Management and Personnel

NAH will provide flight planning and preparation of flight line maps, all qualified technical personnel to manage and complete the survey, supply of all technical equipment and spares, processing, interpretation and delivery of TDEM data on a daily basis. NAH will provide written status on a schedule to be discussed. These reports will provide a general summary of the project's progress highlighting:

- ∞ Deliverables achieved;
- ∞ Deliverables remaining, progress and expected delivery; and
- ∞ Issues and concerns affecting specific deliverables and the project schedule, or any other aspect of the project.

NAH will develop the Survey Plan and the Management Plan and ensure that all safety requirements relating to civil aviation will be adhered to. Special care will be taken to ensure that all applicable Aviation Regulations (Federal or otherwise) will be respected. NAH will also establish the bases of operation and the field data processing facility.

NAH survey staff will include a pilot, mechanic, field manager, geophysicist, and a field technician. The total survey crew will consist of five (5) people.

### B.1 Project management

The on-site Field Manager will be responsible for the overall success of the project and ensure delivery of all required products is on time and within specifications. He/She will oversee the field operations and data acquisition as well as coordinate and manage each day's sorties and to ensure that all data is collected as efficiently and safely as possible. The Field Manager will also:

- ∞ Communicate with the Sunnyside Gold Corporation Contract Representative on a daily or as-required basis; and
- ∞ Ensure specifications are being met and adhered to.

## **Appendix C      QA/QC**

NAH ensures quality control of the project by using advanced data acquisition and data processing (in field and office) techniques. These include:

### **Data acquisition:**

- ∞ Advanced auxiliary and electronic navigation ;
- ∞ Elimination of bias and need for regular calibrations;
- ∞ "Next Day" processing available; and
- ∞ Experienced field and office geophysical staff.

### **Data processing:**

- ∞ Custom processing and interpretation; and
- ∞ Advanced Imaging Techniques.

NAH will focus on the highest level of quality during data acquisition and for all data products delivered. We will ensure that the survey is performed within the appropriate airborne geophysical industry best practice and standards. We strive to take advantage of the latest technologies and techniques in the airborne geophysical industry and, where appropriate, combine with the NAH Surveys QA/QC Plan and Manual.

NAH will be responsible for adjustment and calibration of geophysical equipment, ensure operation meets specifications, and will maintain quality control of processing and interpretational procedures applied to the data.

## **Appendix D Health, Safety, Environment and Community**

### **D.1 NAH's HSE policy statement**

NAH is continuously working on improving our Health, Safety and Environment management in order to maintain a safe and healthy work environment and an environmental friendly business performance. We strive to reach the highest global standard of HSE management within our business.

The safety of our employees, the public and our operations is of primary importance. We actively support the efforts of all personnel to strive for the goal of a safe and healthful work environment. To achieve this goal, we outline and implement specific standards and procedures at our offices and other premises and at field locations from which we operate.

Our office and crew managers at all locations are responsible for administering the program and are held accountable for its success. Our employees are also held accountable for following the rules and procedures set forth by NAH and for contributing to our overall achievement.

The elimination of accidents and losses due to accidents is an important responsibility for all of us. This responsibility is being accepted and implemented with the same commitment to excellence as are our other business objectives relating to customer satisfaction, sales and operating costs.

NAH is committed to undertake all work activities with due regard for the environment and to meet applicable legal and other requirements and, where possible, go beyond to achieve corporate targets of Zero Harm to the Environment. This includes all facilities and field locations. Our airborne field operations do not harm or disturb nature and we do our utmost not to disturb wildlife. It is a corporate policy never to leave waste and to keep fuelling and similar operations under strict control in order to prevent spillage.

### **D.2 Objectives**

It is NAH's objective to:

- ∞ Maintain high standards for health, safety and the protection of the environment at our offices and other premises and at field locations from which we operate;
- ∞ Ensure that these standards are incorporated into the design and planning of all aspects of our operations;
- ∞ Communicate these standards to all employees and subcontractors;
- ∞ Enable our employees to work in a safe manner by giving them the necessary information, instruction and training.
- ∞ It is incumbent upon Management to strive for the safe operations of our survey platforms and facilities and to promote an effective and proper understanding with all employees and subcontractors on matters which relate to health, safety and the environment.
- ∞ All NAH employees are required and encouraged to cooperate with Management on all matters relating to health, safety and the environment and to take reasonable care while at work to ensure the health and safety of themselves and others who may be affected by their actions.

## D.3 HSE management system

### IAGSA compliance

NAH is an active member of the International Airborne Geophysics Safety Association (IAGSA) and, as such, adheres to the Recommended Practices and Guidelines of IAGSA. The NAH HSE Management system has not yet reached its full extent and is constantly being updated as required. Our primary focus has been on the development of a safe system of work for our field operations based on a logical, well-thought out approach that includes components which identify and document the hazards, safety precautions, and safe working practices associated with our field activities. The system ensures that our field operations are compliant with the IAGSA Safety Manual. The logical approach of our system embraces four steps:

- ∞ Identify the hazards and assess the task ;
- ∞ Define safe methods and operational procedures;
- ∞ Implement and train people ; and
- ∞ Monitor the system.

### Risk Assessment

An important component within NAH's HSE Management system is risk assessment. Our safe system of work and the planning of fieldwork is based upon four types of risk assessments:

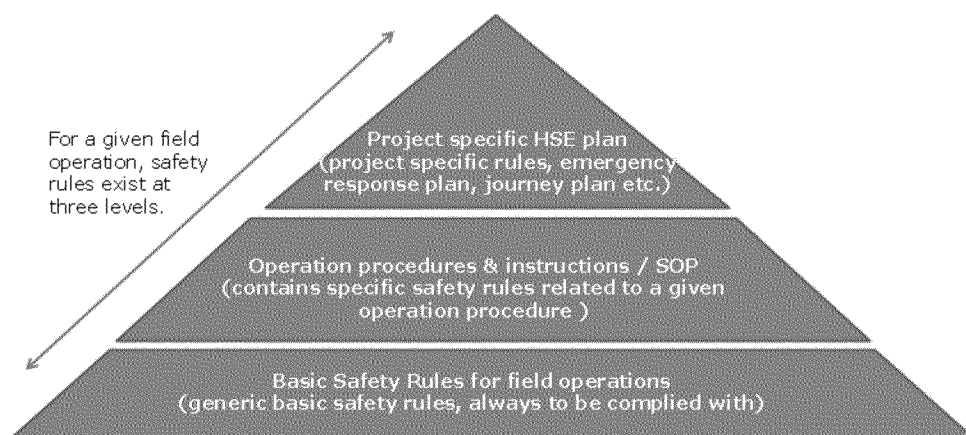
- ∞ Design Risk Assessment  
Must be performed when designing, developing or modifying the geophysical field operation equipment (survey system).
- ∞ General Task Risk Assessment  
Must be performed prior to the planning of standard operational procedures
- ∞ Survey Risk Assessment  
Also referred to as a Job Safety Analysis. This type of risk assessment must be performed when planning specific survey projects.  
  
This type of risk assessment must include the ground field work of a given survey operation if specific known site -conditions and/or customer requirements create circumstances that causes the planned work to differ from standard operations.
- ∞ On-site Risk Assessment  
Must be performed when having hazardous one -off assignments performed by NAH personnel or by other personnel working under the instruction of NAH globally. This type of risk assessment must also be performed when a planned field work task, for whatever reason, differs from the standard procedure.

The risk assessments form the basis for identification of safety measures, the need for education & training, for use of personal safety equipment, and for monitoring and inspection.

## Safe System of Work

The management of risks (safety measures) is described in a set of procedures, instructions, rules, requirements and guidelines, with the purpose to act as a reference and supplement to our operational instructions, procedures and manuals. Our safe system of work consists of the following three levels of documents:

- ∞ The NAH Basic Safety Rules for field work;
- ∞ Operational procedures and work instructions (SOP);
- ∞ Approved written procedures (if necessary);
- ∞ Project specific HSE Plans; and
- ∞ Safety Method Statements (Journey management Plan) which usually is the responsibility of the aviation operator .



In combination with this system, our project management and sub-contractor management form compliance with the IAGSA Safety Manual. Our project management and sub-contractor management is currently being extended and improved in order to fully document this compliance.

## Training of employees

A core component within NAH HSE Management system is the training of employees. To ensure that our safe system of work is being communicated properly, understood by employees and applied correctly we do our utmost to:

- ∞ Ensure that supervisors know they should implement and maintain the safe system of work;
- ∞ Ensure adequate training is carried out for employees and supervisors; and
- ∞ Stress the need to avoid short-cuts and to stop work when faced with an unexpected problem until a safe solution can be found.

Besides a set of requirements for the technical education/skills of our field personnel, we have implemented requirements for basic safety training. Only persons who meet these basic safety training requirements and who have received a site introduction are allowed to work on NAH's operation sites. The basic safety training requirements for persons working on the NAH field operations includes:

- ∞ Responsibilities on site
- ∞ Basic First Aid & CPR
- ∞ Basic Fire Fighting
- ∞ The use of personal protective equipment
- ∞ Working around a helicopter
- ∞ Radio communication
- ∞ Hand signaling
- ∞ Electricity safety precautions
- ∞ Lifting techniques
- ∞ Prevention of trip & fall accidents
- ∞ Knot binding
- ∞ Hooking training

Besides this, the field personnel are trained in how to perform a risk assessment of an unplanned-task (On-site Risk Assessment).

NAH requests from the sub -contractors, whom we engage in field operations, that they ensure a high level of training as well. Personnel from labor-providing sub-contractors must meet the training requirements as the internal NAH personnel as described above and aircraft operators are required to comply with the training guidelines outlined in the IAGSA Safety Manual.

### **Monitoring**

The NAH HSE Manager is responsible for advising our Managing Director, respective Departmental and Field Managers and all other NAH personnel on matters relating to health, safety and the protection of the environment. The HSE Manager assists NAH Field Management in establishing the necessary HSE standards, procedures and training required for working in the field.

The HSE Manager reviews reports on accidents, incidents and near misses and ensures that a full investigation is carried out and appropriate remedial action implemented. The HSE Manager also conducts or, where appropriate, engages suitably qualified independent consultants to conduct independent health, safety, and environmental inspections and audits of NAH field operations and prepare the necessary reports for management review.

## **D.4 Safety management in the field**

### **Project Manager**

The NAH Project Manager is responsible for ensuring that all field personnel, for whom he/she is responsible, know that they are required to adhere at all times to NAH's HSE Management System and all supporting standards and procedures, and that employees exposed to hazards know the described safety precautions and are trained for performing the work in a safe way.

The Project Manager furthermore ensures that specific responsibilities for health, safety and protection of the environment are properly defined and delegated, and that all NAH facilities utilized by his subordinates and all associated equipment are of such a design and construction and are so maintained as to minimize the risk to health, safety and the environment.

It is also the responsibility of the Project Manager to ensure the preparation of the site specific HSE plan and as such the preparation of a Job Safety Analysis and for the establishment of a site specific emergency response plan and flight following procedure. This requires close cooperation with the aviation operator and communication with people living in the survey area, local authorities and governmental departments and agencies, as well as Sunnyside Gold Corporation, in advance of all survey flying.

### **Field Manager**

It is the responsibility of the Field Manager, at the field site, to ensure that a daily safety session (Job Safety Briefing) is being conducted on site before work commences. The Field Manager should make arrangements for all NAH personnel and/or contractors, under their control, to be thoroughly briefed on the known hazards associated with each job, prior to commencement of the work so that they fully understand what is required of them, together with any precautions that need to be taken. This would be completed with information provided by the aircraft operator. Reports from these meetings must be kept.

It is furthermore the responsibility of the Field Manager to ensure that risk assessments are being conducted whenever a situation causes the work to be performed in an unplanned way (non-standard operation) and that all changes from standard operations immediately are being thoroughly communicated to all involved personnel (tool-box talks). Reports from tool-box talks must be kept.

### **Employees**

It is the statutory responsibility of all NAH field personnel to take reasonable care of the health and safety of themselves and of other persons who may be affected by their actions or omissions at work. All personnel must familiarize themselves and comply with the provisions of our safe system of work and any specific rules or procedures relating to health and safety at work and environmental protection.

Employees are obligated to promptly report any near misses, accidents, incidents or dangerous occurrences to the Field Manager and cooperate fully in any investigation and to cooperate with NAH management on matters relating to health, safety and the protection of the environment.

Field personnel working on a NAH field operation must furthermore ensure that any equipment including vehicles issued to them, or for which they may be responsible, is correctly used and properly maintained.

### **Aircraft Operator**

The aircraft are maintained and operated by NAH/Southern Helicopter Inc. These Aircraft are required to comply with the NAH HSE requirement and their safe system of work is to be approved by NAH.

On a survey operation, the aviation operator works under the general project management responsibility of NAH and is requested to provide all relevant documentation related to the aircraft related activities for approval by NAH prior to project kick off, e.g., Risk Assessments; Journey Plan; Flight Following Plan; Emergency Response Plan; Procedure for aircraft maintenance; Training documentation; Accidents & Incidents Reporting.

## **D.5 Accidents & incidents**

NAH always complies with the accident & incident reporting requirements set out by national and/or local legislative authorities in the geographically areas in which we operate. NAH has never had any accidents that caused injuries to persons or environment, but we encourage our employees to report all work related incidents and we always conduct a full investigation in order to establish proper safety precautions. The most hazardous part of our survey operations is related to aviation and as a part of our subcontractor management we require accident & incident statistic from our aviation business partners in order to evaluate their safety management.

## **D.6 Equipment**

The SkyTEM system has been routinely flown on environmental, engineering, mineral, and oil and gas exploration projects around the world. The carrier frame, towed beneath a helicopter, has been optimized to be rigid and to reduce noise from vibrations and has been a reliable and robust platform for the transmitter and receivers.

SkyTEM bird-towing technology is based on and built from the best and most substantial materials available on the market in order to avoid any unplanned or accidental mechanical release of the system. The system is designed so that all parts are connected with wires and lines to avoid the possibility of any parts falling from the frame.

Connection to Helicopter: The upper end of the main tow cable is anchored to helicopter cargo hook with a high-quality stainless steel shackle certified to carry a load of 5,500 kg. Redundancy is built in to help ensure safety and a double chain of ropes is employed on the main tow cable.

The towing system segments and components are inspected and mechanically tested on a regularly scheduled basis. NAH field technicians inspect the tow system segments and components for possible damage or defects before each flight.

## **D.7 Environment**

Environmental requirements will be considered during planning and will always be done in conjunction with the aircraft operator.

## **D.8 Corporate social responsibility**

NAH strives to become a reliable and trusted business partner through enhanced dialogue-oriented involvement with customers, stakeholders, and employees and we always enter into honest and productive dialogue with stakeholders to achieve shared solutions.

## Appendix E Corporate Experience and Past Performance

### *Broken Hill Managed Aquifer Recharge*

In April 2013, XRI processed and interpreted nuclear magnetic resonance (NMR) data collected as part of a multi-year study by Geoscience Australia (GA) to evaluate the feasibility of managed aquifer recharge in the Menindee Lakes area of New South Wales for water supply for the municipality of Broken Hills. Menindee Lakes is connected to the Darling River and would use high flows in the Darling River as a source of water for the recharge. The NMR data acquired in 2013 provided detailed hydrogeological data that were used to calibrate historical NMR logging data collected in 2011 by GA. The data were compared and integrated into a 20,500 line-mile AEM survey that was collected in 2009 (Lawrie and others, 2012; Lawrie and others, 2013; Tan and others, 2013; Tan and others, 2014; Lawrie and others, 2015).

### *Pagan Island Commonwealth of the Northern Mariana Islands*

In July of 2013, a joint XRI Geophysics and US Army Engineer Research and Development Center geophysical exploration program took place on Pagan Island in the Commonwealth of the Northern Mariana Islands. XRI acquired 500 line-miles of airborne magnetic, dc resistivity, and time-domain electromagnetics. The geophysical surveys were conducted to characterize the active volcano for hazards and to develop a preliminary groundwater framework for the island. The results of these airborne and ground-based investigations provided a magnetic total field map of the island, a magnetic susceptibility earth model, a map of Curie Depths under Pagan Island, the locations of freshwater reserves as well as freshwater/saltwater interfaces in the investigated areas (Exploration Resources International, 2014; Asch and others, 2014; Irons and others, 2015).

### *Osage Nation Oklahoma*

In September 2013, XRI and NAH completed an AEM survey of Osage County, OK. This investigation was conducted to assist in the delineation of saline groundwater beneath the county in support of ongoing water resources investigations for the Osage Nation. Data from the survey's findings were used to improve the conceptualization of the groundwater flow system and support dataset inputs for a groundwater model of the region. The AEM survey totaled 1,550 line-miles across Osage County with variable flight-line spacing. In addition to the airborne survey, ground-based time-domain electromagnetic data were acquired at four sounding locations for AEM data quality assurance (Pierce and Abraham, 2014).

### *Lower Elkhorn Natural Resources District, Nebraska*

Beginning in August 2013, XRI conducted an AEM survey and built a hydrogeological framework of the area near the towns of Clarkson and Howells, NE for the Lower Elkhorn Natural Resources District (LENRD). The purpose of the study was to address the water resource concerns of the district in the area between Clarkson and Howells, where record groundwater declines were experienced in 2012, prompting the LENRD to seek additional information on the groundwater availability of the area. Results of this study indicated the AEM system had depths of penetration in excess of 900 ft with detailed resolution of the subsurface. In addition to the airborne survey, ground-based time-domain electromagnetic data were acquired at four sounding locations for AEM data quality assurance. The study also confirmed the presence of limited aquifer materials (sands and

gravels) within the Quaternary glacial deposits. An added benefit of the study was the ability to map the contact of the Quaternary system and the underlying Cretaceous bedrock, which could provide an additional source of groundwater for Clarkson and Howells (Abraham and others, 2013; Abraham and others, 2014).

#### **Madison, ~~Nebraska~~**

Beginning in August 2013, XRI conducted an AEM survey and assembled a hydrogeological framework of the area surrounding the town of Madison, NE. The purpose of the study was to address the water resource concerns of the town of Madison, NE. In addition to the airborne survey, ground-based time-domain electromagnetic data were acquired at four sounding locations for AEM data quality assurance. Results from the 47 line-mile survey indicated the presence and extent of aquifer materials (sands and gravels) and aquitard materials (silts, clays) within the Quaternary glacial deposits beneath the survey area, and provided potential target areas for exploration and development of a new municipal well field (Carney and others, 2014).

#### **Lower ~~Platte~~ ~~South~~ ~~Natural~~ ~~Resources~~ ~~District~~**

In August 2013, XRI conducted an AEM survey totaling 827 line-miles over three separate flight blocks in southern Butler and Saunders Counties, NE which resulted in a hydrogeological framework of the area between the towns of Dwight, Brainard, and Valparaiso. The purpose of the study was to assist the Lower Platte South Natural Resources District (LPSNRD) in groundwater management planning in the northwest part of the district. In addition to the airborne survey, ground-based time-domain electromagnetic data were acquired at four sounding locations for AEM data quality assurance. Results indicated the presence of aquifer materials in paleovalleys, aquitard thickness, potential groundwater recharge areas, connectivity of surface water and groundwater, and Cretaceous bedrock topography (Carney and others, 2014).

#### **Permian ~~Basin~~ ~~Texas~~**

In February and July 2014, XRI and NAH acquired a cumulative total of over 4,664 line-miles of AEM survey data over several areas of the southern Permian Basin in West Texas for a partnering water supply company. The objective of these flights was to characterize brackish aquifer conditions in Cretaceous and Triassic strata on the southern edge of the Permian Basin to provide water supply support for the energy industry. At some locations, ground-based dc resistivity, audio-magnetotelluric, time-domain electromagnetic, and seismic surveys were conducted to ensure the quality of the AEM data and to provide further insight into delineating the contacts between the underlying strata. Borehole geophysical data was also collected and integrated into the interpretations (Abraham and others, 2015).

#### **Lower ~~Elkhorn~~ ~~Natural~~ ~~Resources~~ ~~District~~**

In October 2014, XRI and NAH completed an AEM survey and hydrogeologic framework of approximately the northwestern half the LENRD centered around the city of Norfolk, NE with a flight-line-grid spacing of 3-5 miles. The purpose of this investigation was to provide an overall general framework of the aquifer resources beneath this portion of the district, and to provide insight into appropriate flight-line spacing required to provide optimal information regarding hydrogeologic conditions. Results indicated the presence and extent of materials comprising the principal Quaternary aquifer in the region as well as aquitard materials present across the district, as well as the hydrogeologic character of the subsurface in proximity to the major surface water drainages crossing the district. The airborne system implemented in this project also allowed for characterization of the entire

Cretaceous bedrock sequence beneath the district and the contact between the Cretaceous strata and the Paleozoic system (Exploration Resources International, 2015).

#### **Missouri Riverbank Filtration System, North Dakota**

In October 2014, XRI and NAH completed an AEM survey along the Missouri River between Bismarck, ND and Garrison Dam on Lake Sakakawea, in support of streambed sediment characterization for sighting a riverbank filtration system planned by the North Dakota State Water Commission. This survey, which covered over 700 line-miles along the Missouri River corridor, provided detailed profiles of the character of the sediments beneath the Missouri River and the adjacent alluvial plain that sit atop Tertiary bedrock strata. XRI also conducted a ground-based resistivity survey of particular areas of interest where a partnering contractor had drilled a series of geologic test holes. This survey, which covered a distance of approximately 4.5 miles, provided greater understanding of the streambed material thickness between the test holes (Exploration Resources International, 2014).

#### **Fort Peck Indian Reservation, Montana**

Also in October 2014, NAH and XRI completed a survey over the Fort Peck Reservation in northeastern Montana, which included the East Poplar Oil Field. This survey collected AEM and magnetic data in support of an ongoing subsurface contaminate plume study. A total of 826 line-miles were flown for this survey (Exploration Resources International, 2014).

#### **Eastern Nebraska Water Resources Assessment**

Also in October 2014, XRI and NAH completed the first phase of an AEM reconnaissance survey over the northern half of the Eastern Nebraska Water Resources Assessment (ENWRA) project area, which covered nearly 900 line-miles within an area between the Platte River valley in the Columbus-Fremont area northward to the Nebraska-South Dakota border. This first phase of the survey was conducted with a grid spacing of 10-20 miles across the Lewis and Clark, Lower Elkhorn, and Papio-Missouri River Natural Resources Districts. In April 2015, the second phase of the AEM reconnaissance survey was completed across the southern half of the ENWRA project area, which covered 685 line-miles over an area between the Platte River valley in the Columbus-Fremont area southward to the Nebraska-Kansas border. This survey included the southern extent of the Papio-Missouri River, Lower Platte North, Lower Platte South, and Nemaha Natural Resources Districts, as well as small sections of the Upper Big Blue and Lower Big Blue Natural Resources Districts. These surveys revealed the extent and character of Quaternary aquifer and non-aquifer materials alike across an area the size of Connecticut and Rhode Island combined, as well as the trends in thickness and structure of the underlying Cretaceous and Paleozoic systems. The hydrogeologic frameworks resulting from these surveys provide greater understanding of the subsurface conditions across district-wide areas, and can assist water resources managers in locating where more detailed, smaller-scale AEM surveys can be conducted in support of water supply and management needs.

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## **Appendix F     Resumes of Key Personnel**